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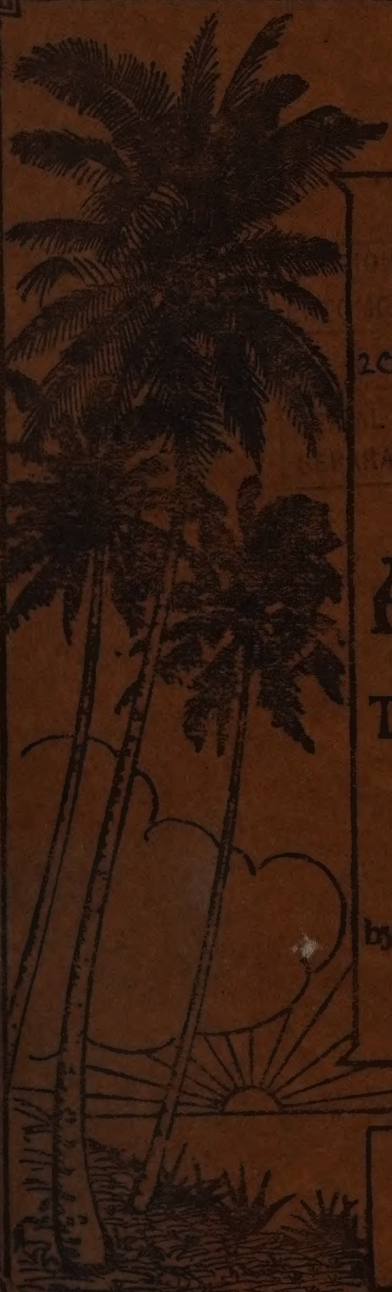

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The
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EDITORIAL

SOIL STRUCTURE

ONE of the most important lines of research on soils today is the study of the crumb structure of soils in its relation to such characters as tilth, erodibility, fertility maintenance, fertilizer retention, percolation and irrigation. The colloidal fractions of the soil exert such powerful physical effects that their importance far outweighs that of the coarser particles. It is particularly the colloidal fractions which influence the physical characters and largely decide the methods of crop husbandry which can be applied successfully. It is a characteristic of the soils of Ceylon that with few exceptions they are low in colloids. The small size of the Island and the generally steep run-off under rain which is frequently torrential results in the silt-and clay-laden waters of streams reaching the sea too soon and too rapidly to permit sedimentation and delta formation such as has produced the great alluvial plains of the Indus, Ganges, Brahamaputra, Mekong and Irrawaddy rivers. The slow accumulation of clay and fine clay in tank beds indicates the character of that fraction of the soil which is generally carried to the sea, where it is deposited in deep waters, but the total quantities so transported are insufficient to build up the ocean floor to tide levels. The coarser fractions are mostly hard, crystalline sands which are quickly deposited in the low lands or, if the rush of water is intense enough, they may form unstable sand-bars on the coral reefs along the coasts. In Ceylon soils we have then, conditions which lead to a subtle form of soil erosion as well as the more obvious surface scouring. There is a steady removal of clay and fine clay fractions in stream waters, though these may not show high amounts of solids in suspension. The ultimate result is on the physical characters of the soils which, losing that part which produces the greatest surface effect, become extremely friable, lose water retentivness, become increasingly subject to leaching of nutrients and more liable to pulverize under cultivation. The point we would emphasize is that very great care must be exercised in all agricultural operations on these soils.

It is specially difficult to handle them under rotational agricultural systems so as to maintain a good physical structure and avoid erosion. The soil moisture range within which such soils can be safely worked is small. When too wet clods form and when too dry there is danger of pulverization. The studies of Joachim and Pandithasekera reported in this number reveal some of the physical properties of Ceylon soils which particularly affect farming operations. They show that the true crumb content is very far below the crude crumb except in the case of the high level soils under a moist, cool climate where the humus accumulation is large and transported sand contents low. It is the soils of the dry, low country which are poorest in true crumb and the least waterstable. These soils also have predominantly small-sized crumbs. The vegetation exerts a marked effect on the crumb, as is well known but the lowering of true crumb content under dry crop cultivation may be specially noted because it is this which is specially dangerous. If these dry zone soils are to be brought under permanent rotational cropping great care will be needed in the methods of tillage and in the choice of the rotation. It is bad husbandry to tear up the land with heavy mechanical implements regardless of its fitness for working and we personally hold the view that very gentle tillage may be necessary. It is possible, if the soil moisture is only slightly below the optimum, to break down the crumb by fast-moving implements. The narrowness of the working range for such soils is a decided hindrance to mechanization since it restricts the time during which a machine can operate without damage to the soil. We have seen tractors rushing over the land followed by a cloud of dust (largely pulverised crumb) in an endeavour to plough or harrow the requisite acreage by a given date. The damage to the soil or its fitness for subsequent crops are often overlooked. The large beneficial effect on crumb content and crumb stability of humic materials indicates a means of ameliorating the trouble, whether by incorporation of organic matter such as cattle dung or compost, or by a grass fallow. There is the further possibility that a crop such as fodder sorghum would be beneficial in the rotations, both of itself and as an indirect source of animal manure. One thing is certain : much careful investigation into systems of agronomy for these soils is necessary to avoid disaster.

SOIL FERTILITY STUDIES

IV INVESTIGATIONS ON CRUMB STRUCTURE AND STABILITY OF LOCAL SOILS

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DEPUTY DIRECTOR OF AGRICULTURE

AND

D. G. PANDITTESEKERA,
ASSISTANT TO CHEMIST

SUMMARY

THE structure of a soil and, in particular, its water-stable aggregate content, controls to a large degree its air and water regimes and hence its resistance to erosion. It is also of importance in the maintenance of fertility. Investigations were, therefore, undertaken to determine the water-stable aggregate content of a number of typical local soils, and its variation with nature of land, vegetation and agricultural treatment. Martin's water-sieving method for the estimation of crumb fractions greater than 0·5 mm. diameter was investigated in regard to its suitability for local soils, and a simple modification introduced to eliminate the appreciable portion of sand and gravel found in the crumb fractions of many of our soils. The procedure as finally adopted for the determination of the "true" crumb content gave results which were highly correlated with those obtained by the Base Exchange Capacity method adopted at Rothamsted. These studies have indicated that—

(i) There are very marked variations in both the "crude" and "true" crumb contents of local soils, the sandy types and the limestone-derived soils of the Jaffna Peninsula being the least and the humic patana soils the most water-stable of the fifty-three samples studied. The soils also varied in regard to the size-distribution of the water-stable aggregates, the patana types having relatively more of the coarse fractions and the Jaffna and other dry zone soils of the finer fractions.

(ii) The "crude" crumb percentages of local soils compare very favourably with those of other tropical and temperate soils. The "true" crumb percentages, except in the cases of the humic and grassland soils, are generally not high, and on the average amount to about 50 per cent. by weight of the "crude" crumbs.

(iii) The nature of the vegetation has a marked influence on aggregate content, natural jungle and forest soils being with few exceptions, superior to those from cultivated or deforested highland areas. Grasses, whether natural or introduced, e.g., Napier, exercise a beneficial effect on structure. Cultivation reduces crumb content in ordinary soils, but on the peaty loams of the patanas, cultivation and manuring appear to improve soil structure to some extent. Paddy soils, like highland soils, vary considerably in water-stable aggregate content.

(iv) The degree of stability of the crumbs as determined by McCalla's water drop method shows considerable variation with soil type. The precision index derived from the correlation ratio between degree of stability and true crumb percentage reveals that only about a third of the variability of the latter is dependent on the former.

(v) Earthworm casts and termite mound earth appear to be superior in crumb content to the soils from which they are derived except when the latter are under grass.

INTRODUCTION

Soil structure or the state of aggregation of the soil particles largely controls the degree of aeration and moisture status of a soil and is, therefore, of great importance in the prevention of soil erosion and the maintenance of soil fertility. A method of evaluting soil structure which has been observed to give results closely related to the soil's productive capacity and resistance to erosion, is the determination of the amount and size-distribution of its water-stable aggregates or crumbs ranging from 0·25 mm. to 10 mm. diameter (1). Russell & Tamhane (2) chose the diameter size of 0·5 mm. as giving the most informative figure for the degree of aggregation of the soils studied. The values obtained for the proportions by weight of the water-stable fractions of a soil have been generally designated the "crumb" contents, but as these crumbs consist of soil aggregates as well as of unaggregated particles of sand and gravel of the same size-range or settling velocities as the former, they are more appropriately termed in this paper "crude crumbs", and the aggregates separated from the sand and gravel, "true crumbs". Russell & Tamhane also demonstrated that a reliable measure of the "true" crumb content of the soil can be obtained by determining the proportion of the base exchange capacity (B.E.C.) of the soil that is in the crude crumb fractions, and recommended the adoption of Schofield's method (3) for this purpose owing to its ease and rapidity of operation.

SCOPE OF INVESTIGATIONS

The Rothamsted water-sieving method for "crude crumb" estimations was adopted by Martin (4) in Uganda for his investigations on crumb structure in relation to pastures and fodders. With a view to determining whether Martin's procedure could, in turn, be modified to give figures for "true" crumbs in concordance with those obtained by Russell's B.E.C. method, investigations were conducted on a number of local soil samples to ascertain—

(i.) the "crude" crumb contents of these samples by Martin's method using
(*a*) a single sieve of 0·5 mm. mesh,
(*b*) a bank of three sieves of mesh varying from 2 to 0·5 mm.,
(ii.) the "true" crumb values of the soils by the method detailed below, and (iii.) the interrelations between the various sets of data obtained and the "true" crumb content as estimated by the B.E.C. method. The modified method having been proved to be satisfactory for comparative purposes, it was adopted for estimating the "true" crumb contents of the more important local soil types, and of the effect of vegetation—forest, pasture and fodder, agricultural practices—cultivation and manuring, and of animal agencies—earthworms and termites, on them. As the water-stable content of a soil depends, to some extent at any rate, on the degree of stability of the individual crumbs under water action, estimations were also made by a modification of McCalla's (5) water-drop method, of the stability of the crumbs of typical samples and of the correlation between this characteristic and the crumb percentages.

The results of the investigations are detailed in Tables I–V.

EXPERIMENTAL

The first stage in the series of investigations made was the estimation of the "crude" crumb content by Martin's method (4) using both a bank of three sieves of mesh diameters 2 mm., 1 mm. and 0·5 mm. and a single 0·5 mm. sieve. Duplicate samples of 100 gm. of dry soil sieved through a 3 mm. mesh were moistened by capillary action overnight and transferred respectively to the top member (2 mm.) of the bank of three sieves (method I) and to the single sieve (method II). The bank of sieves and the single sieve were each placed in a pail of water and moved up and down gently a number of times until the crumbs in the sieves remained well defined. In the case of the bank of sieves, each sieve was removed in turn from the top downwards when the crumbs on them had reached a state of stability. The fractions on the sieves were then air-dried separately and weighed, and the percentages of "crude" crumb on original soil calculated. The "crude" crumb fractions were then washed through the respective sieves till only the sand and gravel particles were left. These were weighed separately, the weights deducted from the "crude" crumb figures, and the "true" crumb percentages calculated. The results for 53 soil samples are set out in Tables I and 1B. In Table 1A, the

correlation ratios, precision indexes and regression equations between the various sets of data are shown.

TABLE I

Comparison of Methods for Crumb Estimates

Sample No.	Location	Soil Type	Crude Crumb% Method I (A_0)	(>0·5mm.) Method II (A_1)	True Crumb% Method I (B_0)	(>0·5mm.) Method II (B_1)
1..	Medawachiya	Dry Zone non-lateritic loams	34	25	14	13
2..	"		30	32	5	6
3..	Ambepussa	Wet Zone lateritic loams	65	58	25	21
4..	"		55	55	24	22
5..	"		16	16	10	10
6..	"		61	57	39	34
7..	"		54	47	20	17
8..	Makalsnagama	Dry Zone non-lateritic loams	32	32	9	8
9..	"		40	46	9	10
10..	Miriguma	Wet Zone lateritic loams	80	83	39	33
11..	"		67	64	18	14
12..	"		66	70	29	26
13..	"		68	47	50	47
14..	"		64	68	25	26
15..	"		68	69	36	36
16..	Welimada	Dry Zone high-land humic loams	73	72	49	49
17..	"		55	56	36	32
18..	Polonnaruwa	Dry Zone loams (lateritic and non-lateritic)	39	51	19	28
19..	"		40	38	25	20
20..	"		37	35	13	11
21..	"		40	34	25	17
22..	Anuradhapura	Dry Zone loams (lateritic and non-lateritic)	49	50	13	11
23..	"		65	71	37	31
24..	"		57	61	16	15
25..	"		50	52	26	23
26..	"		37	59	16	14
27..	"		44	45	14	13
28..	Naba Illuppallama	Dry Zone non-lateritic loams	42	41	20	21
29..	"		48	44	18	14
30..	"		32	30	10	8
31..	Monaragala	Dry Zone lateritic loams	35	40	13	14
32..	"		55	60	40	42
33..	Jaffna	Dry Zone lime-stone soils	13	14	5	6
34..	"		19	19	11	11
35..	Middeniya	Dry Zone non-lateritic loams.	39	43	15	14
36..	"		38	33	15	11
37..	Hakgala	Wet Zone high-land peaty soils	48	55	31	32
38..	"		47	61	27	29
39..	"		70	73	42	41
40..	"		71	74	42	40
41..	"		77	76	49	49
42..	Weeraputa	Wet Zone loams	52	59	39	29
43..	"		53	54	27	23
44..	Karainagar	Dry Zone sands	17	24	2	5
45..	"		9	12	1	2
46..	Bogatalawa	Wet Zone high-land peaty soils	62	62	50	49
47..	"		67	70	45	42
48..	"		64	58	48	46
49..	"		64	61	54	51
50..	Kurugoda Uyanguda	Wet Zone lateritic loams	40	39	12	11
51..	"		70	76	40	41
52..	Lahugala	Dry Zone loams	50	49	14	13
53..	"		48	59	24	25
		Mean	49·7	50·9	25·0	23·7
	Significant difference		6.7		5.4	

TABLE 2A

	Correlation Ratio	Regression Index	Regression Equation
A1, A2	[illegible]**	[illegible]	[illegible]
B1, B2	[illegible]**	[illegible]	[illegible]
A1, B1	[illegible]**	[illegible]	[illegible]
A2, B2	[illegible]**	[illegible]	[illegible]

** Indicates significance.

TABLE 3B

Grain Size Distribution of Typical Soil Samples

Sample No.	Locality	Fine Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Total	Fine Gravel %	Coarse Sand %	Medium Sand %	Fine Sand %	Total
[illegible]	Antigonish	25	30	15	40	100	5	5	5	5	20
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Kingsville	20	25	15	40	100	20	12	4	[illegible]	36
[illegible]	Kingsville	15	20	16	49	100	20	12	10	[illegible]	50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Tillsonburg	17	25	16	42	100	12	9	10	[illegible]	31
[illegible]	Tillsonburg	21	21	20	70	100	24	12	12	[illegible]	48
[illegible]	Tillsonburg	22	21	17	40	100	22	10	9	[illegible]	41
[illegible]	Bonnieglen	25	20	20	45	100	22	15	15	[illegible]	54
[illegible]	Willowdale	20	22	20	38	100	20	12	12	[illegible]	44
[illegible]	Bonnieglen	25	17	16	42	100	20	12	12	[illegible]	38
[illegible]	Lacombe	4	10	35	45	100	1	5	10	[illegible]	26
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	Fallis	1	2	10	78	100	1	1	3	[illegible]	5
[illegible]	Fredericton	5	5	22	68	100	5	6	12	[illegible]	37

RESULTS AND DISCUSSION

[illegible]

indicated in regard to the high percentages of sand and gravel in the crumbs of many of our soils, not much significance can be attached to them unless they relate to the same type of soil subjected to comparative treatments. The natural corollary to this conclusion is to ascertain what reliance can be placed on the "true" crumb figures as obtained by the method finally adopted in these studies. With this object in view six samples of the widely-prevalent types of soils were subjected to detailed study. Determinations of their "crude" and "true" crumb contents by the procedures described and of their "true" crumb contents by the base exchange capacity (B.E.C.) method were carried out, and the results set out in tables II and IIB. Table IIA furnishes the statistical information derived from the data of Table II.

Table II—See Page 125

Table IIA

	Correlation Ratio	*Precision Index*	*Regression Equation*
ZB	·9953*	90·4	B = 1·2Z — 4·0
YB	·8864*	53·7	B = 0·9Y — 18·9

* Indicates significance.

TABLE IIB

True Crumb Percentages

Soil No.	(1) *B.E.C. Method*	(2) *Calculated from Crude Crumbs*	(3) *Calculated from True Crumbs*
1	47·3	57·3	49·6
2	58·8	61·2	58·7
3	53·6	39·6	52·0
4	10·8	23·8	12·2
5	22·9	22·4	24·3
6	23·5	19·4	20·8

An examination of the figures in these tables reveals that there is an extremely high positive significant correlation between the B.E.C. data and the 'true' crumb percentages obtained by our method. The precision index derived from the correlation ratio between these two sets of figures shows that no less than 90 per cent. of the variability of the B.E.C. per cent. of the crumbs is dependent on the 'true' crumb percentage, and only 54 per cent. on the 'crude' crumb content. Table IIB discloses the close correspondence between the B.E.C. figures for 'true' crumbs and those calculated from the regression equation between the former and our "true" crumb values.

TABLE II

Comparison of Crude and True Crumbs (> 0·5 mm.) and Base Exchange Capacity (B.E.C.) Percentages

(1) Location of Sample	(2) Crude Crumb % (Y)	(3) True Crumb % (Z)	(4) B.E.C. of Whole Soil mgm. equiv./100 gm.	(5) B.E.C. of Crude Crumbs mgm. equiv./100 gm.	(6) B.E.C. of True Crumbs mgm. equiv./100 gm.	(7) Total B.E.C. of Crumb Fraction mgm. equiv./100 gm.	(8) Ratio of (7) to (4) % (B)
Ambepussa	77·9	38·0	13·1	9·96	16·3	6·19	47·3
Mirigama	89·0	45·6	14·9	9·84	19·2	8·76	58·8
Welimada	65·0	40·1	12·2	10·06	16·3	6·54	53·5
Anuradhapura	47·5	7·1	11·6	2·65	17·7	1·26	10·9
Moneragala	45·9	16·9	9·7	5·05	13·7	2·32	23·9
Middeniya	42·6	14·0	6·8	3·75	11·4	1·60	23·5

The method having been proved satisfactory, it was adopted for the studies on the variations in the "true" crumb content of local soils with type of land and soil, nature of vegetation, agricultural treatment, &c. The results of these determinations have partly been discussed with reference to Table I, but are re-classified in Table III. In this table, in addition to the "crude" crumb data, the "true" crumb figures as determined by our procedure and calculated from the regression equation indicated in Table IIA, are furnished for comparison.

TABLE III

The Effect of Type of Land and/or Treatment on Crumb Percentage

Sample No.	*Location.*	*Type of Land or Treatment*	(1) % *Crude Crumb* (> 0·5 *mm.*)	(2) % *True Crumb* > 0·5 *mm.*)	(3) % *True Crumb* (*B.E.C.*) (*Calc.*)
1	Peradeniya E. S.	(*a*) Fallow land (unweeded)	61	45	58
		(*b*) Napier grass ley	65	51	65
2	Polonnaruwa Farm	(*a*) Virgin land	40	20	28
		(*b*) Ploughed land	37	11	17
		(*c*) Napier grass ley	39	28	38
		(*d*) Paddock	40	17	24
3	Moneragala	(*a*) Highland	40	14	21
		(*b*) Jungle	60	42	54
4	Lahugala	(*a*) Highland	49	13	20
		(*b*) Jungle	59	25	34
5	Middeniya Farm	(*a*) Grass area	43	14	21
		(*b*) Rotation area	31	11	17
		(*c*) Arable land	19	10	16
		(*d*) After 3 years Napier grass	22	13	20
6	Karadian Aru	(*a*) Arable land	19	7	12
		(*b*) After 3 years Napier grass	37	26	35
7	Mirigama	(*a*) Jungle	83	33	44
		(*b*) Highland (jak plantation)	64	14	21
		(*c*) Estate Farm	70	26	35
	Mirigama (Ambana)	(*d*) Paddy land	67	47	60
8	Ambepussa	(*a*) Napier grass ley	58	21	29
		(*b*) Low-grazing fodder	16	10	16
		(*c*) Grass sward	57	34	45
		(*d*) Owita land	47	17	24
9	Anuradhapura	(*a*) Paddock	71	31	41
		(*b*) Highland (rotation area)	50	11	17
		(*c*) Highland (under citrus)	52	23	32
		(*d*) Paddy land	61	15	22
10	Welimada (Wilson's Plains)	(*a*) Patana	73	49	63
		(*b*) Highland (cultivated)	55	32	42
11	Karagoda Uyangoda	(*a*) Fodder area	39	11	17
		(*b*) Pasture	76	41	53
12	Hakgala	(*a*) Natural patana	55	32	42
		(*b*) Natural patana (sub-soil)	61	29	39
		(*c*) Patana (cultivated and dunged)	73	41	53
		(*d*) Forest (top soil)	74	40	52
		(*e*) Forest (sub-soil)	76	49	63
13	Bopatalawa	(*a*) Natural patana	62	49	63
		(*b*) Patana (cultivated and dunged)	61	51	65
		(*c*) Fodder area (limed)	70	42	54
		(*d*) Fodder area (limed and dunged)	58	46	59
14	Maha Illuppallama	(*a*) Cultivated brown loam	41	21	29
		(*b*) Cultivated red loam	44	14	21
		(*c*) Cultivated grey loam	30	8	14
15	Jaffna (Tinnevelly)	(*a*) Rotation area	14	6	11
	Jaffna (Vadukoddai)	(*b*) Highland	19	11	17
16	Karainagar	(*a*) Pasture	24	5	10
		(*b*) Highland	12	2	6
17	Weerapana	(*a*) Jungle	59	29	39
		(*b*) Cultivated	54	23	32
18	Makalangama	(*a*) Jungle	32	8	14
		(*b*) Highland	46	10	16
19	Medawachiya	(*a*) Highland	25	13	20
		(*b*) Paddy land	32	6	11

It will be noted that the nature of the vegetation has a marked influence on the aggregate content, natural jungle and forest soils being, with few exceptions superior to those from cultivated (highland) or deforested areas in respect of "true" crumb content. Grasses, whether natural or introduced, e.g. Napier, exercise a beneficial effect on structure. This is exemplified in 1 (*b*), 2 (*c*), 5 (*d*), 6 (*b*), 8 (*a*) and (*c*) and 11(*b*). The observations of previous workers are thereby confirmed (4, 8). Cultivation reduces crumb content in ordinary soils, but on the peaty loams of the patanas, cultivation and manuring appear to improve soil structure to some extent. Compare, for instance, the figures 12 (*a*) and 12 (*c*), 13 (*a*) and 13 (*b*) with those of 4 (*a*) and 4 (*b*), 7(*a*) and 7 (*b*), 17 (*a*) and 17 (*b*). Paddy soils, like highland soils, vary appreciably in water-stable aggregate content: 7 (*d*), 9 (*d*) and 19 (*b*) are illustrative. In regard to the effect of type of soil within a limited area, the figures for the Maha Illuppallama soils are noteworthy. The ill-drained, sandy grey loam is the least water-stable, the brown loam most so and the red loam, intermediate between the two.

TABLE IV

Comparison of Crumb Percentages of Termite Earth, Earthworm Casts and Adjacent Soils

Sample No.	*Description of Sample and Location*	*Crude Crumb %*	*True Crumb %*
1	Kalawewa, earthworm casts	20	16·5
1A	Kalawewa, soil adjacent	30	13
2	Kalawewa, earthworm casts	35	24
2A	Kalawewa, adjacent grass sward soil	41	33
3	Hingurakgoda, earthworm casts	14	6
3A	Hingurakgoda, soil adjacent (red earth)	27	3
4	Hingurakgoda, earthworm casts	24	21
4A	Hingurakgoda, natural grassland soil adjacent	34	21·5
5	Maha Illuppallama, termite mound soil	30	15
5A	Maha Illuppallama, adjacent soil	36	13
6	Pelwehera, termite mound	61	30
6A	Pelwehera, adjacent soil	33	25

It has been observed by a number of investigators (8) that earthworms exercise a markedly beneficial effect on soil structure. With a view to testing this out in regard to local soils, samples of earthworm casts collected from two locations in each of two areas and of the soils from which they were derived were examined for crumb content. The results shown in table IV bear out to some extent what has been found by other workers (8) but with this difference, viz., that if the land from which the samples were collected was under natural pasture, the top soil was superior to the wormcasts in "true" crumb content. A preliminary study was also made to ascertain the effect of termites (white ants) on soil structure. Samples of termite mound earth and of the adjacent soil were compared in respect of soil structure. Here again the termite earth appeared to be slightly superior to the parent soil in "true" crumb content. Further work on this aspect of the subject should yield more conclusive information.

A factor which would presumably determine to a large degree the ultimate weight of the crumb fractions in a soil sample is the degree of water-stability of the individual crumbs. McCalla (5) devised a simple method for

ascertaining the relative stability to water of the soil crumbs. He determined the number of drops of water falling from a fixed height at a uniform rate of flow which was required to disintegrate a small lump of soil placed on a 0·5 mm. sieve. Twenty determinations were made on each sample and the mean drop value calculated. Preliminary tests carried out by us indicated that the weight of soil clod used by McCalla (0·15 gm.) was, owing to the sandy and gravelly nature of many of our soils, too small, and the lump size was accordingly increased to 0·3 gm. To stabilize the rate of flow of the drops, water was led into a burette with a side inlet from an aspirator bottle, and the height of water in the latter and the burette cock adjusted to give a rate of fall of 3 seconds per drop. The results obtained with a number of normal soils are shown in Table V, in which is also recorded the "crude" and "true" crumb percentages of the samples.

TABLE V

Crumb Stability (McCalla) and its Relation to True Crumb and Crude Crumb (> 0·5 mm.) Content

Sample † *No.*	*No. of drops (degree of stability)* X	*Crude Crumb %* Y	*True Crumb %* Z
1A	100	61	45
2A	14	40	20
2B	20	37	11
2C	39	39	28
2D	32	40	17
3A	66	40	14
3B	63	60	42
4B	16	59	25
5B	25	32	11
7B	42	67	14
7C	31	66	26
8A	14	32	8
8B	10	58	21
8C	9	16	10
9A	17	71	31
9B	13	50	11
9D	23	61	15
10A	166	73	49
10B	131	55	32
Mean	43·7	50·4	22·6

TABLE V A

	Correlation Ratio	*Precision Index*	*Regression Equation*
XY	·1306	1·0	Y = 0·147X + 44·0
XZ	·7591*	34·9	Z = 0·215X + 13·2

* Indicates significance. † See Table III.

It will be noted that there is much variation between samples in respect of drop number, the figures ranging from 9 to 166, against 8 to 49 for "true" crumb percentages. Other samples, paticularly those of high organic

matter content, gave considerably higher figures. Thus a sample from Bopatalawa (humic patana soil) required over 1,270 drops before disintergration was discernible, while one from a Napier grass area at Peradeniya gave a drop number of 670. These soils incidentally have high "true" crumb contents, but not of the order that their drop numbers might indicate. Their very high water-absorbing capacities would partly account for this discrepancy. The statistical data worked out for the figures recorded in table V reveal that while there is a fairly high significant correlation between drop number and "true" crumb percentages, only about a third of the variability of the latter is dependent on the former, i.e., soil stability or drop number. This result is not altogether unexpected. Apart from the reason just discussed, the pre-treatment of the soil for crumb estimations (i.e., saturation with water by capillarity), and the fact that the estimations are different, the one measuring the total weight of crumbs and the other the stability of the individual crumbs—would account for the low interdependence figure obtained. Be this as it may, the water drop technique affords a useful guide to the action of water by rain drops and hence, to its resistance to erosion. This method also confirms what has already been demonstrated from other aspects of these studies, viz., that the "crude" crumb figure is no criterion whatsoever of the true aggregate content of the majority of our soils.

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THE EFFECT OF DAY LENGTH ON HEADING TIME IN RICE

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1.—INTRODUCTION

ALTHOUGH the classification of Ceylon paddies into date-fixed and period-fixed types is generally possible, information relating to factors affecting heading time is meagre. Observations by Lord and de Silva (1931) and Haigh (1936), on the effect of sowing date on the age of the two pure-lines, *Kohumawi*-B. 11 and *Suduheenati*-1 CPY-15, have hitherto been the only records on Ceylon paddies. The present paper provides data on sowing-date effects covering a wider range of varieties.

Neither Lord and de Silva nor Haigh attempted an explanation of the marked variation that they had observed, in age with sowing date. The profound influence that the photoperiod had on flowering even in tropical latitudes, was, at the time, insufficiently appreciated. Probably the earliest demonstration of the striking effects on age, of the relatively small day-length differences that obtain in the tropics was by Rhind (1935). He showed that the late Burmese sesamum, *hnangyi*, was a short-day plant which flowered in twelve-hour or shorter days. Extension of the photoperiod to thirteen hours completely inhibited flowering.

Scripchinsky (1940) offered a photoperiodic explanation of Lord and de Silva's and Haigh's data. The *Suduheenati* pure-line, 1 CPY–15 was, according to him, a day-neutral type, comparable with Rhind's early sesamum, *hnanyin*. Scripchinsky saw in the less-than-one-hour difference between the longest day in the year and the shortest, a complete explanation of the behaviour of the *kohumawi* pure-line, B–11. He suggested that B–11 headed normally only when sown in the *maha* season, because it was a short-day plant adapted to the continuously decreasing photoperiods which prevail in this season, and that it should be possible to induce early heading in January—or December—sown *kohumawi* by subjecting it to an artificially shortened day of 11 hour 40 minutes or less. The experiments reported herein include a test of Scripchinsky's theory. The effects of the length of the photoperiod, of the duration of induction, and of the age of seedlings at the time of induction, have also been studied.

2.—EFFECT OF SOWING DATE ON HEADING TIME

Investigations of the effects of sowing date took the form of monthly plantings, and were conducted at Peradeniya (elevation : 1540 ft.) Bellana (sea level) and Egaloya (sea level)on the following range of Ceylon pure lines :—

Variety.	Index Number of Pure Line.	Age* in Months.
1. *Kohumawi*	B.11	6
2. *Kurulutuduwi*	b.13	5½–6
3. *Suduheenati*	1 CPY.19	4
4. *Honderawala*	1254	4
5. *Madael*	39 YM137	4
6. *Dahanala*	37 YM2014	3
7. *Balamawi*	31009	3
8. *Kaluheenati*	39 YM3254	3

The data relating to these stations are presented in Tables I, II and III Floods caused numerous gaps in the data. The Peradeniya series was the most satisfactory, and covered a period of two years. Some of the Peradeniya data have been plotted with length-of-day data in fig. 1. The Bellana and Egaloya data are complementary ; recording commenced at Bellana, and, when this station was closed, continued at Egaloya.

TABLE I

Records made at the Peradeniya Paddy Station, of the interval between sowing and the appearance of blooms in fifty per cent. of the plants

Sowing Date.	No. of Days from Sowing to Blooming.			
	Kohumawi. B. 11.	*Kurulutuduwi.* b. 13.	*Suduheenati.* 1 CPY 19.	*Dahanala.* 37 YM 2014.
29.11.46	200	141	91	76
29.12.46	> 365	> 365	85	74
1. 2.47	> 365	> 365	86	74
1. 3.47	> 238	> 238	79	72
1. 4.47	238	226	88	67
1. 5.47	219	203	101	65
1. 6.47	190	187	82	71
1. 7.47	—	—	—	—
1. 8.47	—	—	—	—
1. 9.47	141	141	82	73
1.10.47	142	142	78	68
5.11.47	149	136	103	77
1.12.47	195	149	91	81
1. 1.48	> 315	> 315	96	77
3. 2.48	> 284	> 284	94	77
1. 3.48	> 254	> 254	84	74
1. 4.48	> 223	> 223	90	74
1. 5.48	> 193	> 193	103	82
1. 6.48	> 162	> 162	—	79
1. 7.48	> 132	> 132	87	80
1. 8.48	> 101	> 101	81	72

* From sowing to harvesting.

TABLE II

Records made at the Bellana Paddy Station, of the interval between sowing and the first appearance of blooms.

Sowing Date.	No. of Days from Sowing to Blooming.						
	Kohumawi. B. 11	*Kurulu-tuduwi.* b. 13	*Sudu-heenati.* 1 CPY 19	*Hondara-wala.* 1254	*Madael.* 39 YM 137.	*Kalu-heenati.* 39 YM 3254	*Daha-nala.* 37 YM 2014
1.12.46	—	—	75	78	78	73	71
1. 1.47	▷301	▷301	80	80	80	80	66
1. 2.47	▷271	▷271	73	81	80	74	67
1. 3.47	▷233	▷233	76	84	83	74	69
1. 4.47	▷212	▷212	76	85	137	75	70
1. 5.47	▷182	▷182	76	85	84	75	71

TABLE III

Records made at the Egaloya Paddy Station, of the interval between sowing and the first appearance of blooms.

Sowing Date.	No. of Days from Sowing to Blooming.						
	Kohumawi. B. 11.	*Kurulu-tuduwi.* b. 13.	*Sudu-heenati.* 1 CPY. 19.	*Hondara-wala.* 1254.	*Madael.* 39 YM 137.	*Kalu-heenati.* 39 YM 3254	*Daha-nala.* 37 YM 2014
1. 6.47	185	175	97	101	99	72	70
1. 7.47	186	176	99	105	102	71	70
1. 8.47	—	—	—	—	—	—	—
1. 9.47	183	—	97	108	102	75	68
1.10.47	—	—	104	106	105	73	75
1.11.47	—	—	—	106	109	73	—

At all stations, three-and four-months paddies tend to be period-fixed, and do not exhibit wide variation in heading time with sowing date. The sowing-to-heading duration in *Dahanala*, for instance, did not exceed eighty-two days, whatever the sowing date. The six-months paddies, on the other land, are extremely sensitive to sowing-date effects, and *Kohumawi*—B. 11 and *Kurulutuduwi*—b. 13 sown between late December and early February failed to flower even after the expiry of twelve months. B. 11 and b. 13 sown between September and November headed normally in five months. That the flowering response of six-months paddies to sowing date is a photoperiodic effect is strikingly suggested in fig. 1. Rapid shortening of day length begins towards the end of July, and the September–November sowings have the benefit of the shortest days in the year. Rapid lengthening of day begins in early February, and sowings made between late December and early February experience the longest days. The shortest and longest days were 11 hours 43 minutes and 12 hours 32 minutes respectively in 1947. It is a remarkable fact that a difference in day length of 49 minutes effected changes in age of over seven months.

3.—THE EFFECTS OF THE PHOTOPERIOD, THE DURATION OF INDUCTION AND SEEDLING AGE ON HEADING TIME

The hypothesis that heading time was a function of the photoperiod was tested at Peradeniya in a factorial experiment, in which an investigation

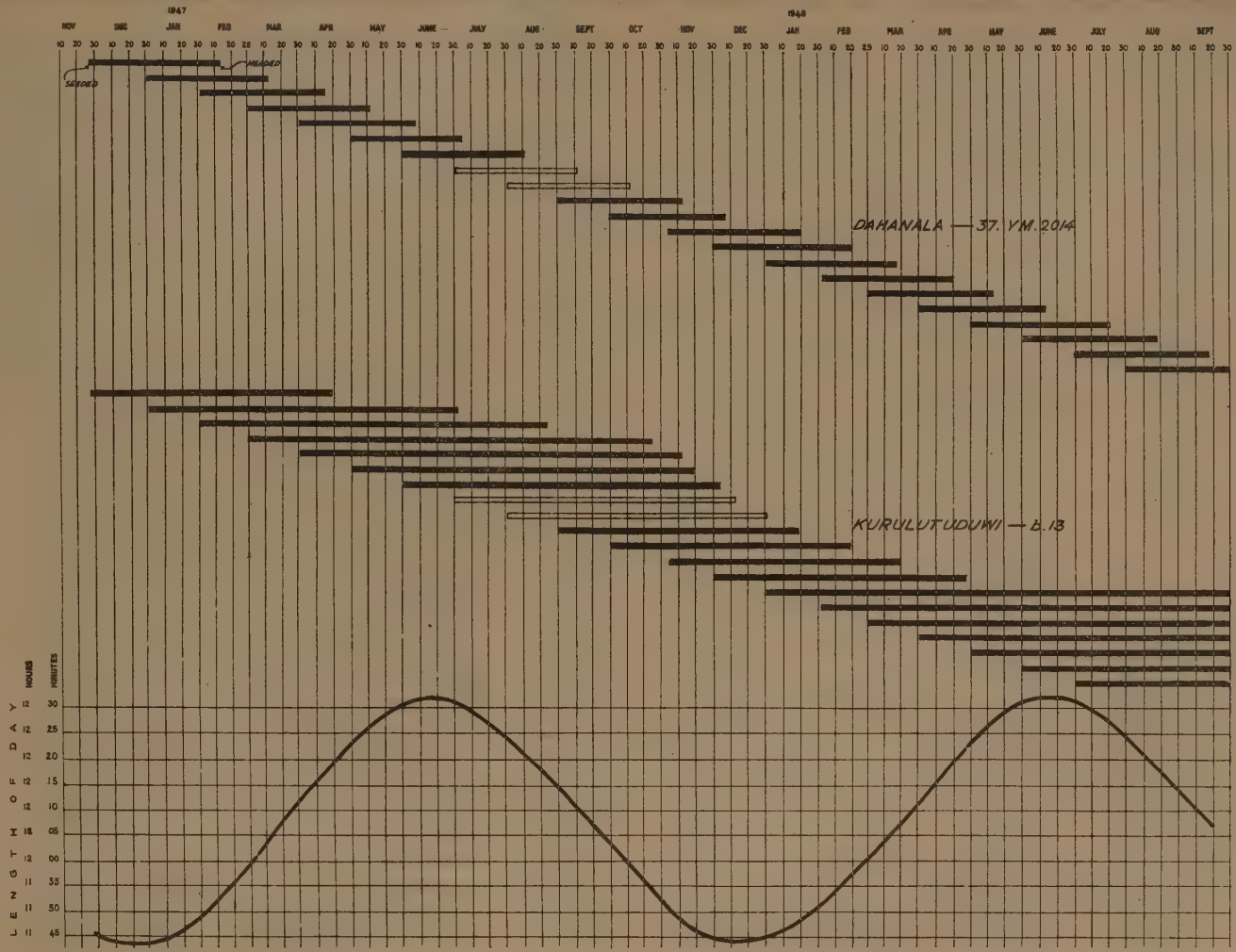

FIG. 1 — PHENOLOGY OF *DAHANALA — 37. YM. 2014* AND *KURULUTUDUWI — 6.13* AT PERADENIYA (LAT. 7° 16′, ELEV. 1540 FT.)

FROM ORIGINAL SUPPLIED BY D. A.

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of the effects of seedling age at time of induction, and of duration of induction was included. The two six-months pure lines *Kohumawi*–B. 11, *Kurulu-tuduwi*–b. 13 were used. The following treatments were tested :—

(*a*) Two photoperiods	..	.. Six hours and nine hours
(*b*) Two seedling ages at time of induction		.. One week and three weeks
(*c*) Two durations of induction		.. Two weeks and continuous induction till emergence.

Sprouted seeds were sown in pots on October 26, 1947. Each treatment was represented by two replicates of 50 plants. Exposure to day light commenced at 6 A.M. Pots subjected to photoperiods of six and nine hours were transferred to an air-conditioned dark room at 12 noon and 3 P.M., respectively. Controls subjected to normal day were maintained. Records were made of the emergence and blooming of every individual.

A summary of the blooming record is presented in Table IV. The figures for sowing—to—blooming intervals would follow a Poisson distribution, and would possess a variance equal to the mean. The subjection of the original data to a pooled analysis of variance is, accordingly, not justified. With transformation to a square-root scale, however, the data would become less non-normal, and the allocation of a common standard error to the treatment means becomes possible. (Bartlett, 1936, and Cochran, 1938). All variance analyses of numbers of days from sowing to blooming were conducted on transformed data.

The variance analysis of the complete data for fifty per cent. blooming is given in Table V. and the treatment means with their standard error are recorded at the foot of the Table. All plants photoperiodically induced till emergence bloomed significantly earlier than controls exposed to normal day.

The elimination of the controls makes the design of the experiment factorial. The variance analysis of the factorial part of the data is given in Table VI. All four main effects attained significance. Seedling ages and induction durations were significant at the 0·1 per cent. point, and the photoperiods at the five per cent. point. The difference between the pure lines showed significance at the one per cent. point. The interaction of seedling age with induction duration was significant at the 0·1 per cent. point, and that of induction duration with pure lines at the one per cent. point. The physical meaning of these interactions on a square-root scale is not completely clear.

The most striking feature of the results is the reduction of the sowing—to—heading interval in these two six-months paddies, to nine—eleven weeks by exposure to a short photoperiod. Under the most favourable conditions of normal day length, both B. 11 and b. 13 take twenty weeks to head.

Two weeks induction of B. 11 plants initially one week old produced no photoperiodic after-effect. Comparable plants of b. 13 showed a slight, but non-significant after-effect.

TABLE IV

Interval between sowing and blooming in one-week-old and three-weeks-old seedlings, exposed to six—and nine-hour photoperiods, for two weeks and continuously till emergence

From sowing to :	Photoperiodically Induced.																Control.	
	At Age of One Week.								At Age of Three Weeks.									
	Induction for Two Weeks.				Induction till Emergence.				Induction for Two Weeks.				Induction till Emergence.					
	9-Hour Photoperiod		6-Hour Photoperiod		9-Hour Photoperiod		6-Hour Photoperiod		9-Hour Photoperiod.		6-Hour Photoperiod.		9-Hour Photoperiod.		6-Hour Photoperiod.			
	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13
Commencement of blooming—																		
Replicate 1 ..	130	108	125	114	59	60	65	68	75	73	85	74	62	63	67	65	131	121
Replicate 2 ..	130	118	131	111	62	58	62	66	75	72	77	73	63	59	67	70	129	118
Fifty per cent. blooming—																		
Replicate 1 ..	141	120	137	124	63	64	71	72	84	82	121	106	67	66	72	70	148	129
Replicate 2 ..	150	127	142	119	66	65	65	73	104	76	109	77	67	63	71	73	137	126
Completion of blooming—																		
Replicate 1 ..	156	134	150	139	72	68	77	75	112	111	141	121	72	72	74	73	156	141
Replicate 2 ..	156	139	158	137	77	72	72	75	134	85	136	85	71	65	77	77	147	135

TABLE V

Variance analysis of interval between sowing and fifty per cent. blooming : complete data, transformed to square-root scale

	Degrees of Freedom.	Sum of Squares.	Mean Square.	Variance Ratio.	5 per cent. Point.	1 per cent. Point.	0·1 per cent. Point.
Treatments	17	80·82	4·75	—	—	—	—
Photoperiodic factors	8	76·88	9·61	73·9	2·51	3·71	5·76
Pure lines	1	1·96	1·96	15·1	4·41	8·28	15·38
Interaction	8	1·98	0·25	1·9	2·51	—	—
Error	18	2·26	0·13	—	—	—	—
Total	35						

	Treatment Means																		Standard Error	Significant Difference.
	Induced at Age of One Week.								Induced at Age of Three Weeks.								Control.			
	Two Weeks Induction.				Induction till Emergence				Two Weeks Induction.				Induction till Emergence.							
	9-Hour Photoperiod.		6-Hour Photoperiod.		9-Hour Photoperiod.		6-Hour Photoperiod.		9-Hour Photoperiod.		6-Hour Photoperiod.		9-Hour Photoperiod.		6-Hour Photoperiod.					
	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13	B. 11	b. 13		
$\sqrt{x}$	12·0	11·1	11·8	11·0	8·0	8·0	8·2	8·5	9·7	8·9	10·7	9·5	8·2	8·0	8·4	8·4	11·9	11·3	±0·51	1·51
x	144·0	123·2	139·2	121·0	64·0	64·0	67·2	72·2	94·1	79·2	114·5	90·3	67·2	64·0	70·6	70·6	141·6	127.7		

TABLE VI

Variance analysis of interval between sowing and fifty per cent. blooming: factorial section of data, transformed to square-root scale

Treatments		Degrees of Freedom.	Sum of Squares.	Mean Square.	Variance Ratio.	5 per cent. Point.	1 per cent. Point.	0·1 per cent. Point.
.. .. ..		15	63·13					
Main effects	Seedling ages	1	5·87	5·87	44·30			
	Induction durations	1	44·89	44·89	338·79			
	Photoperiods	1	0·88	0·88	6·64			
	Purelines	1	1·58	1·58	11·92			
First order interactions	Seedling ages × induction durations ..	1	6·93	6·93	52·30			
	Seedling ages × photoperiods . ..	1	0·51	0·51	3·85			
	Seedling ages × pure lines	1	0·06	0·06	0·45			
	Induction durations × photoperiods ..	1	0·00	0·00	0·00			
	Induction durations × purelines ..	1	1·75	1·75	13·21			
	Photoperiods × purelines	1	0·00	0·00	0·00			
Second order interactions	Seedling ages × induction durations × photoperiods	1	0·54	0·54	4·08	4·49	8·53	16·12
	Seedling ages × induction durations × pure lines	1	0·02	0·02	0·15			
	Seedling ages × photoperiods × purelines ..	1	0·04	0·04	0·30			
	Induction durations × photoperiods × pure lines	1	0·05	0·05	0·38			
Third order interactions	Seedling ages × induction durations × photoperiods × purelines	1	0·01	0·01	0·08			
Error		16	2·12	0·1325				
Total ..		31	65·25					

An induction duration of two weeks produced pronounced photoperiodic after-effects in plants initially three weeks old ; the reduction in the sowing-to-heading interval was three weeks in the instance of B. 11, and six weeks in the instance of b. 13.

Both the photoperiods, nine hours and six hours, induced marked earliness over the controls subjected to normal day-length. The superiority of the nine-hour photoperiod to the six-hour, though not striking, was significant.

4.—THE EFFECT OF DURATION OF INDUCTION ON HEADING IN PADDY SOWN OUT OF SEASON

The factorial experiment reported above investigated photoperiodic effects on heading in B. 11 and b. 13 sown at the normal planting time. It will be remembered that B. 11 and b. 13 sown during the period late December to early February, refused to flower even after the expiry of 12 months. The following experiment set down at Peradeniya tested the effect of short photoperiods on B. 11 when sown out of season. A detailed investigation of the effect of varying durations of induction was superimposed.

Sprouted seed of B. 11 was sown in pots on December 23, 1947. Three weeks-old seedlings were subjected to nine-hour photoperiods for induction durations ranging from 0 to 38 days. The treatments were represented by varying numbers of replicates of 30 plants.

The results are presented in Table V. Earliness increased with duration of induction. Induction for seven days produced no apparent impression on heading ; both control plants and plants induced for seven days failed to flower even after eleven months. Induction for thirty-three and thirty-eight days resulted in a shortening of the sowing-to-flowering interval to eighty-two and seventy-five days, respectively. When the plants were thirty-three days old, the flower primordia were already evident. Continuance of induction beyond 33 days appears to have accelerated emergence. Photoperiodic effects are apparently not limited to the initiation of flower primordia.

TABLE VII

Interval between sowing and blooming in B. 11 seedlings exposed to a 9-hour photoperiod for varying durations.

Pot No.	Induction Duration in Days.	Number of Days from Sowing to : Commencement of Blooming.	50 per cent. Blooming.	Completion of Blooming.
1	0	> 330	> 330	> 330
2	0	> 330	> 330	> 330
3	7	> 330	> 330	> 330
4	14	77	102	> 112
5	21	70	78	97
6	28	69	74	95
7	33	64	72	86
8	33	62	66	81
9	33	62	65	74
10	33	68	74	83
11	33	65	71	81
12	38	61	65	74
13	38	63	69	77
14	38	66	68	72
15	38	64	70	78
16	38	67	71	78

5.—DISCUSSION

Numerous workers (Yoshii, 1926, Noguchi, 1927 and 1930, Fuke, 1931, Kondo *et al.* 1932 and 1934, Tabata *et al.* 1934, Miyashiro, 1935, Eguchi, 1937, Beachell, 1943, Sircar, 1944, and Sircar and Parija, 1945) have reported photoperiodic responses in paddy. All these reports, however, relate to varieties native to the higher latitudes. Beachell (*ibid.*) observed, for instance, in the material tested by him, that varieties which had originated in a latitude above 30 north were photoperiodically sensitive, and that varieties native to latitudes near the Equator were relatively insensitive. The demonstration of a high degree of photoperiodic sensitivity in varieties native to Ceylon (5° 55′—9° 50′ north latitude) is accordingly of considerable interest. Not only has Scripchinsky's surmise been proved to be correct, but a degree of sensitivity unsuspected by him has been demonstrated. The factorial experiment showed striking responses to both nine-and six-hour photoperiods ; B. 11 and b. 13, which under the most favourable conditions of natural day length flower in 20 weeks, completed blooming in 9–11 weeks, and have been shown to be potentially as early as the period-fixed 'short-aged' varieties.

In the instance of the two-weeks induction of seedlings initially one week old, interpretation of the failure to produce a photoperiodic after-effect is difficult. The need for further detailed analyses of factors affecting the onset and duration of the photophase, particularly as a preliminary to genetical studies of the developmental phases into which the "age" of a strain of paddy resolves itself, is evident.

The later and more detailed investigation of induction durations completely confirms the results of the factorial experiment. Where photoperiodic after-effects are involved, heading would be the integrated result of the accelerating effect of the short photoperiod, and the depressing effect of subsequent subjection to natural long day, the production and activity of the "florigen" and "antiflorigen" of Cailahjan (1937) being presumably involved. In the absence of methods of separating the opposing effects, interpretation of the results is difficult. Finally, it may be mentioned that although throughout the paper, reference has been made in the traditional manner to the effect of day length, it is the duration of darkness that is material.

SUMMARY

In experiments on the effect of sowing date on heading time, conducted at Peradeniya, Bellana and Egaloya, three-and four-months varieties were observed to be period-fixed, and six-months varieties to be date-fixed. The data presented suggest that flowering response is largely a photoperiodic effect. A difference in day length of 49 minutes effected changes in age of over seven months.

The effects of the photoperiod, of the duration of induction and of seedling age on the heading time of the six-months pure lines, *Kohumawi*—B. 11 and *Kurulutuduwi*—b. 13 sown in season were investigated. By exposure to nine-and six-hour photoperiods, the sowing-to-heading interval was reduced from twenty to 9–11 weeks. The nine-hour photoperiod effected greater earliness than the six-hour period. An induction duration of two

weeks produced pronounced photoperiodic after-effects in plants initially three weeks old. One-week-old seedlings did not exhibit the onset of the photophase.

The effect of duration of induction was investigated in the purelines, B. 11 and b. 13 sown out of season. Control plants failed to flower even after twelve months. Exposure for 38 days, to a nine-hour photoperiod induced flowering in 75 days. The effect of the photoperiod did not appear to be confined to the initiation of flowering primordia.

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PROGRESS IN PASTURE WORK IN THE HUMID LOWLAND REGION

BY

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IN a previous paper (10) by the author an account was given of the early trials in establishing pastures for livestock in the agricultural stations of the wet lowlands and the problems associated with that effort. The present paper deals with the progress made since then and also indicates the pasture position as it now stands.

The humid lowland region comprises the south-western portion of the Island extending inland to an elevation of about 500 feet. It is subject to the influence of both the north-east and south-west monsoons but differs from the dry zone in that the total precipitation during the south-west monsoonal season from May to September is above 20 inches. The annual rainfall which is zonally distributed from 75 to 150 inches is suitable for the growth of good pasture but the mean annual temperature which shows little variation from 80°F is too high for the long standing, proved grasses (rye grass, cocksfoot and timothy) and legumes (clovers) of the temperate regions. There is, however, much greater diversity of tropical grasses and legumes in the world than in the temperate zone though there are few pastures which have been established for controlled grazing or are as high in productivity. Little work has so far been done in the selection of suitable species of grasses and legumes for the different parts of the wet and arid tropics but in recent years more attention is being directed to the problem of establishing and maintaining good pastures in many tropical countries not only for the purpose of feeding livestock but also for improving the fertility of the soil.

The type of land suitable for establishing pastures in the wet lowland zone is mainly that on which coconuts are grown—the small holdings and the larger estates where coarse grasses and inferior legumes thrive and on which most of the cattle in the zone are reared. The soils are mainly reddish brown, lateritic loams derived from igneous or gneissic rocks and show a pH value ranging from 4·80 to 6·80, while along the coastal belt occur the bleached white sands (cinnamon soils) and the greyish white sands formed from Pleistocene and sub-recent deposits (7 and 8). There also occur small fields of generally low land in proximity to towns in which water or Mauritius grass (*Brachiaria purpurascens* (Raddi) Henrd is grown for supplying cut fodder to dairy cattle. These fields are heavily manured with the refuse from towns and are kept well weeded. In addition there are a few plots of the perennial forage crops—Guinea (*Panicum maximum* Jacq.) and Napier grass (*Pennisetum purpureum* Schum.) maintained by some dairies and coconut estates which rear cattle and supplement rough grazing with these cut fodders. There are

no natural meadows except those which are subject to periodic inundations when the rivers and streams which adjoin them rise to flood levels. Unfortunately, little land is left in this zone for establishing pastures, but most coconut estates are suitable and the light shade provided by the palms is in fact of advantage both to the stock and the pasture components under the conditions of strong sunlight which prevails in the tropics. While the investigations which are in progress are conducted mainly on arable land on the agricultural stations of this zone for the purpose of establishing good temporary pastures for stock to be rotated after 5 to 6 years with arable crops and also for restoring fertility in the soil, the data can be applied to coconut holdings and estates which can serve the dual purpose of producing crops from the palms and of raising livestock on the inter-cultivated pastures. The value of a grass cover in protecting the soil from erosion through the binding action of the mass of fibrous roots, the resistance offered by the foliage to the impact of heavy rain and the better crumb structure is not sufficiently appreciated. Pastures bring above an increase in organic matter through the decay of the plant and animal residues and the porosity of the soils is increased. The improvement effected on coconuts can be gauged from the rise in the yield of nuts of the crop at Horana Station where 10,778 nuts were picked for the first 10 months of 1948,* being the highest figure over all previous years, the pastures being established in 1946 on sloping land under a 5-acre block of coconuts.

The work on pastures has now reached a stage when better strains of the grasses and legumes selected for this zone are being isolated and tested and the technique of grazing management is being determined. The selection of strains for seed viability is also receiving attention.

Pasture components.—Sufficient data have now been obtained for making recommendations of the components of suitable pasture mixtures. As the seeding of pastures has not yet been found successful the compounding of seed mixtures cannot be undertaken and recommendations can only be made of the particular components for pastures on good and poor soils.

A. *For good soils.*

1. *Grasses*—*Brachiaria distachya* Stapf, *Paspalum dilatatum* Poir—Dallis grass
2. Legumes—*Alysicarpus vaginalis* D. C.—(S. *Aswenna*), Alyce clover, *Stylosanthes gracilis* H. B. and K.,—Brazilian lucerne, Stylo.

B.—*For poor soils.*

1. *Grasses*—*Brachiaria miliiformis* Chase,—Fallow panic, *Panicum maximum* Jacq—Guinea grass
2. Legumes—*Stylosanthes gracilis* H. B. and K.

For all soils, the most suitable miscellaneous herbs for supplying the mineral salt requirements of the stock and for standing up to grazing while not assuming the proportions of weeds are *Asystasia gangetica* T. Anders.—(S. *puruk*) and *Ipomoea cymosa R. & S.*—(S. *madhu*).

* Figures available up to October 1948 at the time of writing the paper.

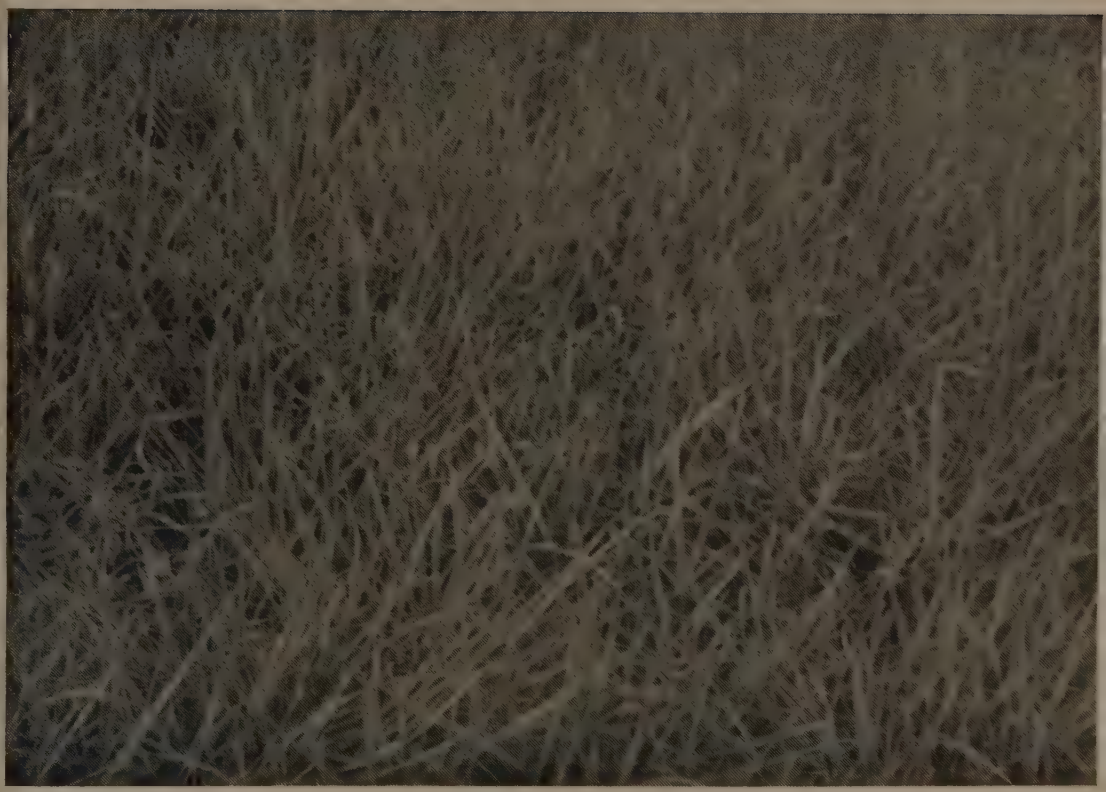

Photo 1.—A close view of a *Paspalum-Alysicarpus* pasture at Ambepussa Farm.

Photo 2.—A pasture block comprising Paspalum and *Brachiaria distachya* (Stapf.) as the grass components and *Alysicarpus vaginalis* D. C. with Stylo as the legumes under rotational grazing. (Ambepussa Farm).

Brachiaria distachya has been successfully established on most of the pasture areas of the stations including a block under coconuts. It grows well in soils with a high organic matter content and it forms a good sward which survives heavy grazing. On poor soils where the organic content is low it tends to die out and to give way to inferior grasses. *B. miliiformis* known as fallow panic in Queensland, Australia (4) is a taller and more vigorous species with longer and broader leaves, but it is inclined to be more stemmy. It is a low fertility demanding species and therefore does better than *B. distachya* on poorer soils. *B. ramosa* Stapf is a species whose fertility demands are even higher than those of *B. distachya*, and on rich soils it is a much superior grass, being more leafy and palatable to stock. Its leaves are characteristically smooth and soft. Planting material is at present limited but it is being multiplied as much as possible and larger areas will be put down to test its response to rotational grazing. At present there are indications that it will be the best pasture grass on good or well manured soils on account of its leafiness, palatability and possible better viability of seed.

Paspalum dilatatum.—Photo 1 is a tufted grass which once established remains persistent. It combines well with the decumbent Brachiaria to form a good compact sward (Photo 2) and on the older pastures subject to regular grazing it tends to spread out. It has so far proved satisfactory but in New Zealand it is reported to develop strong rhizomes which make it useful only for permanent pastures and not for land which is to be periodically ploughed up for arable cropping in rotation with temporary pastures (6), while in Australia it is reported to be sod bound and unthrifty after a few years and requires therefore to be ploughed up (3). Guinea grass which has a tussock habit can be grown successfully in association with the spreading, semi-erect types such as *Brachiaria*. It is drought resistant and its fertility requirements are not high but cattle do not graze it down closely and as a result hard fibrous tillers develop at the base to a height of 4 to 5 inches. These, however, eventually decay with the trampling of the plants during grazing by the animals. Guinea grass grows better than *Paspalum* on the poorer soils and should be planted in combination with *B. miliiformis* on such soils. It can also be grown satisfactorily with *B. distachya* (Photo 3). It makes a good mixture with *Stylosanthes* as reported upon also in Queensland (4).

These grasses which have been recommended as suitable for pastures, produce abundant seed even within a few months of planting cuttings or sets but they cannot be satisfactorily raised by seed unlike the pasture grasses in temperate countries and hence propagation by vegetative means has to be resorted to. Different treatments such as scarification and disintegration of the glumes with dilute sulphuric acid have so far proved ineffective. This now remains the greatest problem in the establishment of pastures in this zone. The failure of range grass seeds to germinate is also recorded from Hawaii (1). Work is now being directed towards the selection of strains and even of other species which will give viable seed. One grass is promising in this respect and that is *Melinis minutiflora* Beauv.—molasses grass which on account of the limited material that is available for study is still under observation. It does not flower regularly as in the case of *Paspalum* and *Brachiaria*, but only towards November and December. Cattle soon relish it once they have become accustomed to it. In view of the fact that it does not seed throughout the year, its nutritive value is likely to be higher than those grasses such as

Paspalum and *Brachiaria* which are continuously in flower. It also is likely to have a higher carrying capacity and in Queensland it is reported to need heavy rotational grazing to keep it in young growth (4).

Brachiaria and *Paspalum* are attacked by paddy fly (*Leptocorisa varicornis* F.) in large numbers when the plots in which they are grown are left ungrazed for over two months for seed production. In the rotationally grazed plots a small proportion of the earheads escape being consumed by stock but the pest, fortunately, on these plots is negligible. *Paspalum* is particularly susceptible to a disease of the earheads which, in the early honey-dew stage when the spikelets become mucilaginous, is caused by *Sphacelia* sp. Later, they become distorted into orange coloured masses due possibly to a *Fusarium* sp. and finally they form elongated and cylindrical sclerotia of *Cerebella* sp. which can be mistaken for ergot. At present, the disease is not serious though it affects the quantity of seed that can be collected. If the pasture is kept too long without grazing and the *Paspalum* is in the honey-dew stage it is best cut for silage. *Brachiaria* is also subject to attack by *Sphacelia* and *Cerebella*.

The two legumes, the exotic *Stylosanthes gracilis* H. B. & K. and the local *Alysicarpus vaginalis* D. C. have proved to be the most satisfactory of those examined. The former develops a bushy habit with a dense, spreading mass of leaves, while the latter forms prostrate branches produced from a short central stem. When growing in association with grasses and even other plants such as *Stylosanthes*, the spreading stems of *Alysicarpus* grow erect and twine closely round the stems of these plants (Photo 4). In many respects *Alysicarpus* resembles the pasture clovers of the cooler regions of the world in its habit of growth and the rôle that it plays in pastures. It is referred to as Alyce clover in the U. S. A. where in the South it makes good pasturage (9) and one leaved clover in Hawaii, but it is not regarded as an important forage plant in that country (5). It flowers and seeds satisfactorily (Photo 5).

Both Stylo and *Alysicarpus* are perennials and can be propagated from seed as well as from stem cuttings. In the case of Stylo only the terminal portions which are more leafy should be used for planting as the basal ends do not sprout readily. Stylo seeds only once a year during March to April. It grows vigorously (Photo 6), develops to a height of about 4 feet and if left ungrazed the stems become woody. Its fertility demands are small—it grows well on hard lateritic gravels as well as on sands with little or no organic matter—and it is remarkably drought resistant. Cattle at first regard it as unpalatable but soon relish it. The following analysis carried out by D. G. Panditteseker, Assistant to the Chemist, Peradeniya, of the hay taken before flowering is given for comparison with lucerne hay before flowering.

	Stylosanthes Per cent.	*Lucerne* (after Halnan) Per cent.
Moisture	10·83	16·0
Ash	6·89	7·3
Protein	16·05	16·2
Fat	1·35	2·4
Fibre	24·50	27·0
Carbohydrate	40.38	31·0
Nutritive ratio	1 : 2·07	1 : 2·4
S. E.	43·06	33·9

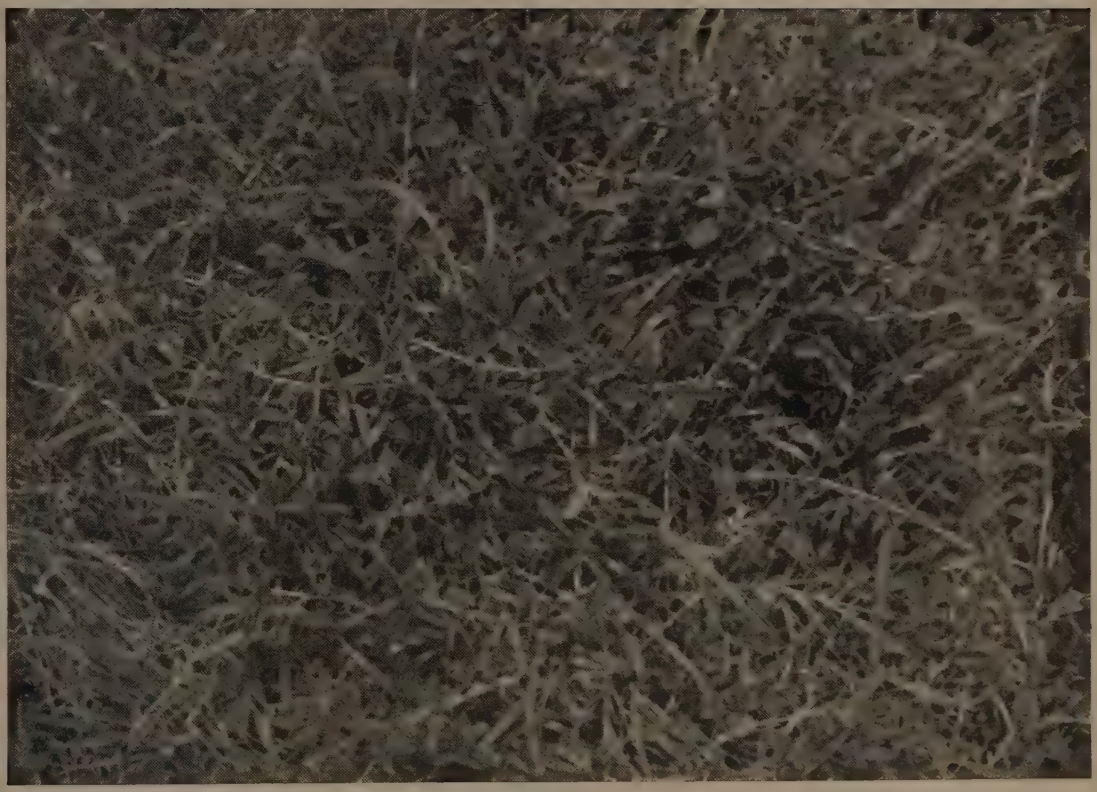

Photo 4.—A close view showing Paspalum and *Brachiaria distachya* (Stapf.) growing in close association with *Alysicarpus vaginalis* D. C. in a pasture block at Ambepussa Farm.

Photo 5.—A close view showing an inflorescence of *Alysicarpus vaginalis* D. C. and the leaves of *Brachiaria distachya* (Stapf.) taken in a pasture block at Ambepussa Farm.

Photo 6.—Stylo planted for seed multiplication at Ambepussa Farm.

There is another species of *Alysicarpus* viz. : *A. rugosus* found growing in the Jaffna Peninsula. It has obovate leaves 4·8 cm. long and 3·8 cm. wide and is a taller and more vigorous growing plant than *A. vaginalis.* Its stems turn woody as they get older but in this respect it is similar to Stylo. It is still under observation and it is too early to make any recommendation of its usefulness as a pasture legume. None of the *Desmodiums* in Ceylon *viz.* : *D. triflorum* D. C., *D. heterophyllum* D. C., *D. heterocarpum* D. C. and *D. ovalifolium* Wall has proved satisfactory. *D. triflorum* is too small a plant to give much forage while *D. heterophyllum* tends to become too aggressive, particularly on the poorer soils. *D. heterocarpum* is too woody and *D. ovalifolium* tends to die out under regular grazing. One more legume *viz.*, *Lespedeza striata* (Thumb.) H. & A. from imported seed is under observation, but its growth is too slow though it has flowered and produced seed from which a second generation of plants has been raised. Temperature conditions in this zone appear to be too high for this legume.

The two herbs—*Asystasia* and *Ipomœa*—are satisfactory. *Asystasia* is an erect herb while *Ipomœa* is a spreading creeper with a deeper root system. Deep rooted plants are preferable as they are able to draw more nutrients from the lower layers of the soil. Both are however palatable to stock and an analysis of their mineral content made by D. G. Panditteseker, Assistant to the Chemist is given below :—

Per cent. composition on dry basis.

	Asystasia	*Ipomoea*
Ash	7·83	6·77
Protein	16·40	12·78
Fibre	37·77	35·20
Fat	·83	1·49
Carbohydrates	37·17	43·76
Moisture on original samples	74·03	75·63

These herbs can be grown from cuttings as well as from seed and though they seed satisfactorily they do not spread as weeds in pastures.

Weed intrusions.—One of the major problems in this region in the establishment and maintenance of pastures is the control of weeds. When land is cleared in the wet tropics weeds develop with a rapidity which is not paralleled in temperate regions. Light, temperature and rainfall are the factors which favour such development. Effective methods of reducing weed growth lie in through preparatory tillage of the land and in maintaining a high nitrogen status of the soil so that the grasses will come up rapidly and smother the weeds through the effect of shading. Weeds are not troublesome in vigorously growing pastures but if soil fertility is allowed to deteriorate then invasion takes place. The following is a list of the common species found in pastures where preparatory tillage or the nitrogen content of the soil has generally been inadequate :—

		Stations on which greatest frequency is recorded.
Grasses	*Dactyloctenium aegyptium* (L) Richt.	Ambepussa and Walpita
	Sporobolus diander Beauv.	do.
	Ischaemum ciliare Retz	Horana
	Eleusine indica Gaertn.	Ambepussa and Walpita
	Digitaria longiflora Pers.	Walpita and Horana
	Perotis indica O. Kuntze	Walpita and Pasyala
	Eragrostis tenella R. and S.	Walpita, Pasyala and Horana

Sedges	*Cyperus zollingeri* *Steud.	..	All stations
Legumes	*Desmodium triflorum* D. C.	..	do.
	Desmodium heterophyllum D. C.	..	Horana, Labuduwa
	Mimosa pudica Linn.	..	All stations
Miscellaneous Herbs	*Mitracarpum villosum** Ch. and Schl.	..	do.
	*Borreria ocymoides** D. C.	..	Horana, Pasyala
	Vernonia cinerea Less.	..	All stations
	*Spermacoce hispida** Linn.	..	Walpita, Labuduwa
	*Hedyotis corymbosa** Lamk.	..	Ambepussa, Pasyala and Horana
	*Aegeratum conyzoides** Linn.	..	Labuduwa
	*Synedrella nodiflora** Gaertn.	..	Ambepussa, Horana
	*Polanisia graveolens** Rafin.	..	do.
	*Mollugo stricta** Linn.	..	All stations.

* Unpalatable to stock.

Although love grass (*Chrysopogon aciculatus* Trin.) is common in all sod bound and unproductive grass areas both under shade and in the open it seldom invades ploughed up land—even though it may have occurred on the same land before—or planted pastures and therefore it is not a weed of consequence. The other inferior grasses listed above which fall in the category of weeds are of low forage value and with the exception of *Digitaria* soon run to seed and produce earheads which are unpalatable to stock. It is not understood why some of the weeds are prevalent in certain stations to a greater extent than on others. *Ischaemum*, for example, is the commonest grass weed at Horana station on a poor lateritic soil where a pasture has been established under coconuts and it assumes complete dominance in patches.

Mimosa is a most troublesome weed though in the early stages of its growth it is nibbled by stock. It however seeds quickly and the young plants which spring up are not readily detected in the pastures. Amongst the herbaceous weeds, *Mitracarpum* and *Borreria* rank high as the most pernicious. The latter flowers and seeds particularly on poor soils when only 2 inches high and once established is difficult to eradicate unless there is a good cover formed by the grasses. It will be observed that with the exception of *Polanisia* and *Mollugo* the herbaceous weeds of pastures are confined to the two families—*Rubiaceae* and *Compositae*.

The establishment and management of pastures.—The importance of a thorough preparation of the soil and adequate manuring to raise the nitrogen and phosphate status of the soil for the establishment of a good cover of grasses and legumes cannot be over emphasized. The nitrogen requirements can be met by the application of compost particularly on poor soils where the organic matter content is low, at 10 tons per acre or by a dressing of sulphate of ammonia or one of the compound fertilizers such as Ammophos or Nicifos at 1 cwt. per acre before planting. This will ensure a good stand of the grasses. For the legumes phosphates are required. Basic slag at 2 cwt. per acre gives good results but if this is not available superphosphate or saphos may be used. Lime at 1 ton per acre is desirable on the highly acid soils and this should be applied in 2 dressings half the

quantity before and the other half after ploughing, care being taken that a sufficient interval is allowed to elapse between the applications of lime and compost.

As stated before, the seeding of the grasses has not proved successful and the planting of stem cuttings in the case of *Brachiaria* and root sets with Paspalum has to be resorted to. The two legumes, however, can be established from seed. After planting grazing can commence in about two months time. The growth of the two grasses *Brachiaria* and *Paspalum* is rapid and they soon come into flower and thereafter continue to flower throughout the year unless well grazed. When sufficient defoliation of the pasture has taken place grazing should cease for regrowth of the foliage during the period of rest through the storage reserves in the stems and roots. It is now recognized that continous grazing is injurious to pasture and intermittent grazing on the system known as rotational grazing should be practised for proper recovery of the foliage. The frequency of grazing varies from one to two months. In general, the herbage is ready for regrazing at the end of a month except during the first 3 months of the year when the period is about 2 months on account of the drier conditions which prevail then. As too frequent grazing in other countries has been found to affect soil structure adversely by the reduction in root development and the depletion of underground reserves of nutrients, it is desirable to extend the period of rest to 2 months. During the seasons of heavy monsoonal rains, however, an interval of 2 months is too long as the grasses with the flush growth become too mature and more frequent grazing at one month intervals is therefore necessary.

As regards the rates of stocking it has been found that 5 to 6 head of cattle per acre grazing for 7 days *i.e.*, 35 to 42 grazing days per acre per grazing period is sufficient with rest spells of 28 to 60 days.

In order to prevent the uneven appearance of the herbage which develops vigorously on the dung heaps, the field should be harrowed when grazing is over to spread out the droppings of the stock, as they do not graze for several months on the herbage where dung has fallen on account of its persistent odour to which they are sensitive.

Establishment of live hedges and shade and wind belts.—The regulation of the grazing intensity on pastures can be achieved by separating fields into paddocks with barbed wire fences or hedges. The expenditure both in posts and wire replacements puts the wire fence at a disadvantage in comparison with a thorny live hedge which is stock proof, checks erosion and acts as a wind belt. The ideal pasture hedge in the U. S. A. is the hardy *Rosa multiflora* Thunb. which is used is a budding stock for tea roses. It is a thorny shrub which does not need cutting back, is easily propagated from seed and attracts beneficial insects such as lady bird beetles. A search is being made for the counterpart of this species for this zone but until a suitable one is found the following thorny climbing shrubs and bushes are recommended :—

Hibiscus furcatus Roxb.	..	(*S. Napirithe*)
Zizyphus oenoplia Mill.	..	(*S. Hin eriminiya*)
Z. rugosus Lamk.	..	(*S. Maha eriminiya*)
Toddalia asiatica Lamk.	..	(*S. Kudumiris*)
Gmelina asiatica Linn.	..	(*S. Demata*)

These species have been planted in mixture and they are periodically cut back so that a strong stout hedge which is effective in keeping out stock

is being built. Amongst the thorny trees, *Triphasia aurantiola* Lour. (the Chinese or Myrtle lime) is being tested.

The establishment of shade trees along the boundaries of open paddocks in desirable for providing shelter to the stock during the hottest part of the day. Although the local Sinhala and the Indian breeds of milk cattle—the Scindi and Sahiwal—kept on the agricultural stations of this zone are able to graze all day long in the open without any ill effect, the provision of shade affords comfort to the animals when they need to lie down and rest after a spell of grazing. As some of the pasture areas on the agricultural stations form part of the system of ley farming it is not possible to establish shade trees within the pasture which will be maintained only for periods of 5 to 6 years before being ploughed up for sowing arable crops in rotation with pasture. But an avenue of shade trees which will also serve the purpose of a wind break along the boundaries will meet this need. The Singapore (18 to 24 months maturing variety) jak (*Artocarpus integra* Merr.) planted 25 feet apart has proved useful in this respect but care has to be taken to prevent it from being eaten down by passing stock which show a partiality for its leaves when the branches are within reach in the early stages of its growth. Individual plants, however, can be protected by wire cages or baskets 5 feet high 2 feet diameter at the top and 1½ feet at the base, but an avenue of young plants is best isolated from cattle by enclosing it on either side by temporary barbed wire fences. A further protection can be effected by smearing the leaves with a slurry of dung which is not easily removed by rain. This recommendation is made because cattle break through fences and damage the jak if any of the fence posts becomes weak through decay. The Rose apple (*Syzium jambos* Alst. = *Eugenia jambos* Linn.) appears more promising than jak in view of its size, rapid growth and immunity to attack by cattle. It should be planted about 25 feet apart and the lower branches should periodically be removed to a height of 4 feet, so as to provide sufficient space for the cattle to shelter under.

Stock management.—The stock should be kept on the pastures both night and day during the grazing period as their dung and urine make a valuable contribution to the fertility of the soil. Stock are known to excrete more at night than during the day and these droppings help in the speedy regeneration of the pastures.

On the better pastures as at Ambepussa Station, calves and dry cows up to 2 months before calving (Sahiwal breed) have been satisfactorily maintained solely on pasture. Milk cows giving less than 1 gallon of milk a day need only about 2 lb. of concentrates per head per day in contrast to previous requirements of about 4 lb. when fed on cut Guinea and Napier grasses, while the few cows that produce up to 2 gallons receive 3 lb.

In each paddock it is advisable that there should be a temporary shed constructed with unsawn timber and a cadjan roof and in it should be placed a box containing a supply of sterilized bone-flour, salt and a mineral supplement. This shed can also serve as an occasional shelter for the animals during the hottest part of the day and when there are heavy spells of prolonged rain.

Stock and particularly milk cows should have access to water in the paddocks. This water should remain cool in the shade of the shelter belts

Photo 7.—A selected strain of *Brachiaria distachya* (Stapf.) under test at Ambepussa Farm.

by placing a concrete trough under the trees and periodically filling it with water, the trough being built at a convenient end to facilitate filling from water carts.

Selection of strains.—The isolation of superior strains of grasses and legumes is one of the most outstanding results of pasture investigations during recent years in some countries of the intermediate (temperate) zone. Amongst grasses, more leafy and persistent strains have been successfully isolated from each variety and seed of the proved strains is made available to growers. A search for better strains of *Brachiaria distachya* and *Paspalum dilatatum* of which a fair amount of material is now available from self sown seed has been made and a number of selections is under observation. One of these (Photo 7) appears superior to the unselected *B. distachya*. It is more leafy and darker green in colour. This strain is being multiplied up for issue of the material. The isolation of other strains for viability of seed as well as leafiness and vigour of growth is in progress. Three forms of *B. ramosa* have been detected and these have been separated and are being compared. Two strains of *Alysicarpus* have been found one of which is more leafy than the other and these are also under test.

Conclusion.—Pastures have now been successfully established and maintained for a period of nearly 3 years in the agricultural stations of the wet lowland zone both on open arable land and under coconuts, the total extent being about 60 acres. These pastures are superior in the yield of herbage and nutritive value to the coarse grasses and inferior legumes on small holdings and coconut estates which provides most of the pasturage for the cattle in this zone. As recommendations can be made of the components of better pastures for good and poor soils and material for planting is available, the establishment of such pastures can now be undertaken by owners of coconut holdings and estates on which a system of animal husbandry can be combined with the production of nuts. At Horana Station, the planting of pastures in coconuts has in the third year of rotational grazing resulted in a large increase in the crop. The cost of establishing these pastures is comparatively high on account of the necessity for hand planting instead of seeding in the absence of sufficiently viable grass seed. But once established these pastures do not need much attention except periodic hand weeding of certain pernicious weeds that may appear especially if the preparatory tillage has not been sufficiently thorough and the soil inadequately manured for the quick establishment of a dense sward. Cattle thrive on these pastures and are in better condition than when fed on cut fodder grasses which are devoid of legumes and herbs and which require to be regularly manured and weeded. In pastures, the labour of cutting and transporting fodder to the sheds where the cattle are fed as in the case of fodder grasses is saved. Pastures also serve a valuable purpose in restoring fertility and in preventing erosion of the soil through the compact foliage and the dense mat of grass roots and those of the associated legumes. Grassland should be regarded as the key crop on which all future agriculture both in the cooler as well as in the tropical regions will pivot. In Ceylon, the most difficult problem that exists is that of raising grasses of good seed producing qualities, so that suitable mixtures of grasses, legumes and herbs can be sown from seed. Efforts are now being directed towards the selection of strains and even the introduction from abroad of new species which will produce viable seed.

Summary

The progress made in pasture work since its commencement in the humid lowlands in 1946 has been outlined and the position which has been reached in the establishment and maintenance of pastures indicated. A satisfactory sward can be established both on open arable land and under coconuts with the following components :—For good soils, *Brachiaria distachya* Stapf and *Paspalum dilatatum* Poir. as grasses, *Alysicarpus vaginalis* D. C. and *Stylosanthes gracilis* H. B. and K. as legumes. For poorer soils, *Brachiaria miliiformis* Chase and *Panicum maximum* Jacq. (Guinea grass) as grasses and *Stylosanthes* as the legume. Although trials are not complete there is every indication that for good soils *B. ramosa* Stapf is an even better grass than *B. distachya*. The viability of the seed of these grasses still remains a problem and they can only be satisfactorily established by vegetative methods. *Melinis minutiflora* Beauv. which is under test is promising in that it produces viable seed and grows vigorously. The selection of strains for leafiness, persistence and even viability of the seed is being pursued. A superior strain of *B. distachya* for leafiness and vigour of growth has so far been isolated.

The legumes can be propagated from cuttings and from seed. Stylo compares favourably with lucerne in nutritive value.

Grazing can commence in 2 months after planting. Rotational grazing is essential for the maintenance of herbage yields, the spells of rest varying from 1 to 2 months, depending on the weather and the time of the year.

Different species of thorny climbers and shrubs are being tested for their suitability as stock proof live hedges separating paddocks. The rose apple (*Syzium jambos* Alst. = *Eugenia jambos* Linn) is a promising shelter tree along the boundaries of the paddocks.

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THE CULTIVATION OF COLEUS ROTUNDIFOLIUS (POIR.) A. CHEV. ET PERROT (COUNTRY POTATO) IN CEYLON

BY

J. S. L. WHITE

AGRICULTURAL INSTRUCTOR

THE Country Potato, **Coleus rotundifolius* (Poir) A Chev. *et* Perrot S. *Innala, Ratala,* T. *Korana-kelangu* is a herbaceous annual having leaves with an aromatic smell resembling mint. The tuber too has a distinct aromatic flavour. It is commonly grown in the low-and mid-country wet zone of Ceylon, during the *yala* season as it germinates only during March–April. It is said to be a native of Tropical Africa from whence it was introduced into Asia. In Ceylon it has never been grown on a large scale, but is confined only to small village gardens, being grown for its tubers which resemble the common potato but are smaller and darker in colour. It is a useful substitute for the potato in the diet of the Ceylon people.

Soils.—Best yields are obtained on sandy loam soils well manured with cattle manure or compost. Fair yields can be obtained from loamy soils but heavy soils are definitely unsuitable.

Varieties.—There are two varieties, one a small tubered variety called " Singhala innala " and the other a larger tubered one called " Rata innala ". The latter yields more and is easier to harvest as the tubers are large. The former is favoured by some people as it is more tasty.

Nursery.—After harvesting in December–January, the plump and healthy tubers are stored, preferably covered with a layer of dry sand, to prevent drying, in a cool well-ventilated room. These are reserved for planting in a nursery when germination commences about the end of March. Raised beds are constructed three feet to four feet broad and any convenient length. These are manured with well decomposed cattle manure or compost at the rate of about forty cartloads or twenty tons per acre. The tubers are planted in rows six inches apart and six inches in the row, one tuber in each hole one and a half inches deep. Two inter-cultivations are necessary, one about three weeks after planting and the other about three weeks later. After each intercultivation, application of cattle urine diluted with fifty per cent.

**Coleus rotundifolius* (*Poir.*) *A. Chev. et Perrot* in A. Chev. Veg. utiles Afr. Trop. Franc. I p. 119 (1905) *Germanea rotundifolia* Poir. in Lam.

Encycl. Suppl. II., p. 763 (1811); *Plectranthus tuberosus* Blume Bijdr. p. 836 (1826) non A. Rich. *Coleus tuberosus* (Bl.) Benth. Sab. Gen. et Sp. p. 59 (1832); *Coleus pariviflorus* Benth. in DC. Prodr. XII., p. 72 (1848.)

water is recommended. Undiluted urine scorches the leaves. If there is no rain, irrigation is necessary, daily during the first week, twice a week during the next three weeks and once a week during the next month. No other attention is necessary, till the cuttings are ready for planting out with the rains, about the end of June or early July.

There are three methods of planting out in the field which will be described later and the amount of seed tubers necessary will depend on the particular method adopted. The methods are (1) planting cuttings in the ordinary way (2) planting coiled cuttings (3) planting cuttings horizontally. For the first method about 8,000 tubers planted in an area of about 2,000 square feet will give sufficient cuttings to plant an acre, while for the second and third methods approximately double and treble the quantities and areas respectively are needed.

If sufficient seed tubers are not available the difficulty of getting enough cuttings can be overcome by planting six inch cuttings from the first nursery, in a second nursery about the end of May or early June and planting out in the field about the middle of August.

If this method is adopted about one-eighth the quantity of seed tubers normally used will suffice. This method is more often the rule than the exception in the Galle district.

Preparation of land and planting.—Innala does not stand water logging, hence planting is best done in ridges, although planting in beds about three feet broad may be done in the drier areas. The land is ploughed about two weeks before planting and harrowed to break up clods. Ridges eighteen inches broad on top are now made either by means of a ridger or with the plough itself. The mammoty is used to complete the ridges according to the required dimensions. They should be eighteen inches broad at the top, twenty four inches broad at the bottom, about eighteen inches high and three feet from centre to centre. Where the area is too small for bullock drawn implements, all the operations are done with the mammoty. If the land is naturally well drained, the ridges and furrows are made on the contour to prevent soil wash. In land liable to waterlogging the ridges and furrows should be at a very slight gradient with shallow silt pits at twenty to thirty feet. Well decomposed cattle manure or compost is applied on the ridges at about ten tons per acre and lightly forked in.

Cuttings with three or four leaves at the top or tender end should be used for planting. In the ordinary method, cuttings about six inches long are planted about three inches deep in rows nine inches apart and nine inches in the row, one cutting per hole and three rows per ridge. This method is quite simple, needs less labour for planting and as stated earlier needs very much less seed tubers. In the coiled method cuttings about nine inches long are used. A length of about five inches of the more mature end is coiled and planted at the same spacing as the first method, in holes three inches wide and two inches deep. The horizontal method, chiefly adopted by villagers in the Galle district, consists in placing cuttings about twelve inches long horizontally across the ridges. Two cuttings are placed on the ridge in opposite directions and almost touching each other. About nine inches of each cutting is on the ridge and three inches outside. The next

pair of cuttings is placed in the same manner about three inches away, and so on. The ridges are now covered with an inch layer of top soil, mixed with cattle manure or compost, if the ridges were not originally manured. In fact if this method of planting is adopted it is more convenient and better to manure after placing the cuttings on the ridge.

In the Colombo district, *innala* is common in most vegetable tracts during *yala* but is never grown on ridges or beds. Holes about one foot square are dug, three feet apart. These are manured with about a basket of cattle manure and four cuttings planted in each hill in the ordinary way. Many cultivators first sow *Hibiscus esculentus*, S. *Bandakka* or cucumber on these hills and plant the *innala* cuttings about a month later. The former is uprooted after its period of usefulness and the *innala* is manured again with cattle manure.

Trials have not been conducted to find out the best method of planting, but from data gathered it appears that the best method is planting coiled cuttings on ridges or beds.

After cultivation.—If a mulch can be applied at a low cost this is recommended as this will reduce weeding costs, otherwise two hand weedings are necessary. One about three weeks after planting and the other about a month later. In certain areas a third weeding may be necessary. Thereafter little or no attention is necessary, as the branches and foliage completely cover the soil and smother weeds. With the first two methods a light earthing-up with soil from the furrows is helpful to encourage rooting at the nodes. This is done after the second weeding.

Harvesting.—The crop is ready for lifting by the end of December or early January, when the plants begin to die. The tubers are formed almost on the surface and there is no difficulty in harvesting which is best done with hand forks. Harvesting of the small variety needs more care, as otherwise some of the smaller tubers will be left behind. Yields vary from three to six tons per acre, the average being about four tons per acre.

Pests and Diseases.—The crop is almost free of pests or diseases. A caterpillar pest sometimes attacks the leaves usually in the nursery, but can be easily controlled by spraying with Lead Arsenate.

Food value and uses as food.—The following is an analysis of *innala* as given by the Agricultural Chemist, Ceylon. The analyses of some other important root crops are also given for comparison :—

	Moisture per cent.	Proteins.	Carbo-hydrates.	Fat.	Fibre.	Mineral Matter.
Innala ..	77·6	1·3	19·7	0·1	0·4	0·9
Manioc ..	67·8	0·8	29·7	0·6	0·7	0·4
King Yam	71·2	1·7	25·5	—	0·6	1·0
Sweet Potato	81·0	1·4	16·0	0·2	0·2	1·2

Innala is usually cooked as a curry and eaten with rice. It is boiled and eaten the same way as manioc and also fried and eaten as chips, which are as palatable as the common potato chips.

Cost of Cultivation.—Innala is one of the most paying food crops. The average cost of cultivation of this crop per acre is given below, based on figures obtained from the cultivation sheet of this crop during "yala" 1945, at the Experiment Station, Peradeniya. The crop grown on a loamy soil yielded five and half tons per acre.

Discription of Work.	Supervisors at Rs. 2·50	Bullock pairs at Rs. 2	Men at Rs. 2	Women at Rs. 1·50	Boys at Rs. 1·50	Cost of Work
Nursery						Rs. c.
Preparation of beds (spreading manure &c.)	1	—	8	5	—	26·00
Cost of 5 cart-loads compost Rs. 7 per cart	—	—	—	—	—	35·00
Planting	—	—	—	4	—	6·00
Weeding	—	—	—	8	—	12·00
Watering during drought	—	—	—	8	—	12·00
Cost of 125 lb. seed tubers at 20 cents per lb.	—	—	—	—	—	25·00
One acre.						
Ploughing	—	2	2	—	2	11·00
Disc harrowing	—	1	1	—	—	4·00
Spike harrowing and collecting weeds	—	½	½	—	2	5·00
Constructing ridges with plough	—	1	1	—	1	5·50
Manuring ridges with compost	—	—	—	6	—	9·00
Cost of 15 cartloads compost at Rs. 7 per cart	—	—	—	—	—	105·00
Completing ridges with mammoty	1	—	20	—	—	42·50
Planting cuttings (including preparation of cuttings)	1	—	—	50	—	77·50
Weeding twice	2	—	—	24	—	41·00
Earthing-up	1	—	10	—	—	22·50
Harvesting with hand forks	1	—	—	80	—	122·50
					Total	561·50

Where preparatory cultivation and ridging are done only with the mammoty the cost will be about Rs. 150 more and the total cost Rs. 711·50. Where preparatory cultivation is done only with the mammoty and no ridging is done the cost will be about Rs. 75 more and the total cost Rs. 636·50.

Taking the average yield of four tons per acre at an average cost of fifteen cents per pound the return is Rs. 1,344 giving a profit of over Rs. 600 per acre.

Conclusion.—Innala has been found to be one of the most paying crops and is also a popular food which can appreciably supplement the diet of the people in Ceylon. It is easily grown, is almost free of pests and diseases and is a suitable crop for any wet zone rotational scheme. There is ample scope for trials and experiments in methods of its cultivation.

SOME STUDIES ON CULTIVATION PRACTICES, FOOD CROPS AND THE MAINTENANCE OF FERTILITY AT THE COTTON STATION, NYASALAND.

H. C. DUCKER AND S. T. HOYLE

EMPIRE COTTON GROWING CORPORATION, NYASALAND

THE cotton industry in Nyasaland is one of African peasant growers, and the work at the Cotton Experiment Station is primarily concerned with cotton problems. But cotton is not grown as a mono-culture, and the chief native food crops of the area are included in the rotation. There is also the universal problem, especially important in Africa, of maintaining and improving soil fertility. This article is not directly concerned with cotton problems, and gives a summary of general investigations that have been undertaken since the Cotton Station was opened in 1930.

SITUATION, ECOLOGY AND SOILS

The Cotton Station is situated at Chitala, some 14 miles inland from Domira Bay, on the plain bordering Lake Nyasa. It lies on about latitude 13° S. and at an elevation estimated at 1,985 feet above sea level. Its lands are close to the main fault system on the western side of the Rift Valley, and immediately to the west of them are the foot-hills, and farther back the main escarpment which forms the dominant feature of the landscape.

The soils of the Station can be roughly classified into two series : one a reddish brown soil on areas with good natural drainage, the other a black soil which occurs where drainage is not so good. An extensive study has been made at Rothamsted of large samples from the two series, and it appears that the general mechanical composition of the two soils is similar, and that the black coloration is due to some peculiar difference in the state of the iron compounds. The black soils show calcium accumulation in the form of nodular concretions which are lacking in the reddish-brown soils, the latter being somewhat more acid. The contrast between the two soils becomes more evident as one moves towards or away from the foot-hills, the red soils predominating and becoming redder towards the hills, and the black soils predominating on lower levels nearer to the lake.

The average rainfall for the past seventeen years is 33 inches, nearly the whole of which falls in the four months from December to March. Within this period distribution is normally good, and heavy falls of over 3 inches per day occur only once or twice each season. Variation in the total rainfall has not been large, ranging from 27 to 36 inches, with the exception of one year when the total reached 46 inches. The distribution is important in determining high or. low yields, but there is no known record of shortage of rain causing a complete crop failure. The mean maximum temperature in December at the beginning of the planting season is about 90° F. falling to 85° F. in May, when the rains are over. During the same period the mean minima fall from 70° F. to 60° F. Extremes recorded to date are 101° F. maximum in November and 42° F., minimum in July.

* From the East African Agricultural Journal, October 1947.

The Station lands have a very mild slope and it has been possible to make all the fields rectangular and standardize their dimensions, which is a great advantage in experimental work. Erosion has been satisfactorily controlled by ridge cultivation and by a few shallow drains to prevent surface wash. In fact, the problem on quite a large area of the heavier lands is to provide surface drainage. In a few places the general slope of about 1 in 150 is exceeded and contour bunds have been made and contour ridge planting has been adopted. The first fields opened still give as good yields as they did seventeen years ago, which may be regarded as proof of the the general efficacy of these mild anti-erosion measures for this particular site.

The lake shore plain lies in a tsetse-fly belt and no animal-drawn cultivation has been possible except for a brief and abortive experiment in keeping work oxen free from trypanosomiasis by regular injections. No tractor-drawn implements have yet been used and the whole of the cultivation to date has been by hand, except for a little ploughing in the two years with the oxen. In fact, it may be said that the cultivation practices on the Station are no more than could be done by an energetic African peasant.

In the account which follows all results quoted are based on statistical experiments.

CULTIVATION PRACTICES

The main experiment, begun in 1938–39, was a factorial one comparing ridge and flat cultivation, early and late preparation of fields, and three levels of digging. This experiment was carried out on a black soil field in good heart for four consecutive years through the normal rotation, and similarly for three years on a brown soil field which had been cultivated by Africans and was in a low state of fertility. Results are therefore available for seven occasions. The fields used formed part of the main Station rotational plan and were cropped in cotton, groundnuts, cotton and maize, in that order. There were also several later experiments concerned with digging only, and others on the frequency and timing of post-planting cultivations on cotton. Where ridge is mentioned in this account, a low ridge some 9 inches in height and 18 inches wide at the base is understood. Such a ridge settles during the season and is seldom more than 6 inches in height at the end of the rains.

Ridge and Flat Cultivation.—Three of the seven occasions were cotton crops, and in each case there was a significant increase in yield from the ridged plots. Out of two maize crops and two groundnut crops, one of each gave a higher yield from the ridged plots, once with maize there was a lower yield, and there was no difference on the other occasion with ground nuts. The yields of the ridged plots were 15 to 20 per cent. higher than the flat plots. The germination was higher on the ridged plots, but when the yields were corrected for final stand at harvest there was still a significant advantage for the ridged plots, showing that the advantage was not due to the greater number of plants. Six weeks after planting samples taken from the cotton crop showed that the ridged plots gave plants with a greater average weight and a higher moisture content, but no difference in height. Fourteen weeks after planting the plants from the ridged plots averaged 5 cm. taller than plants from the flat plots.

Ridge planting is justified if for no other reason than erosion control, and is doubly worth while as higher yields are obtained. It is suggested that the reason for the advantage is that nitrogen is not leached away so quickly from a ridge, as most of the rain will sink into the ground in the furrow. There is no direct evidence of this, but the higher moisture content of the young plants is suggestive.

Time of Preparation of Fields.—The local African cultivator usually delays the cleaning up and preparation of old fields until the very end of the dry season, and seldom completes the work until after the rains have begun. Although it is known that in this area the highest yields are obtained from planting as soon as possible after the rains begin, traditional African

methods are often sound, and it was thought worth while to include this factor in the main cultivation experiment. The usual reason advanced for this habit of late preparation is that it entails less work ; a field cleaned early may grow a second crop of weeds and tree-root suckers, and after rain has fallen the soil is easier to work, though few do more than burn weeds and trash in heaps. One possible reason for late clearing might be that bare fields are exposed to the very hot sun of the latter part of the dry season, and the humus content of the surface layers might be destroyed. The amount of ground cover on the " late " plots and the time of " early " preparation varied with the previous crop. On land emerging from rest there was dense cover, and preparation of " early " plots (digging and ridging as needed for the different treatments) was completed by the first half of May. After a cotton crop the cover was of medium intensity and preparation was completed in July. After groundnuts there was practicially no cover and preparation was completed in April. As maize was the last crop in each field, there was no trial of the effect of maize trash cover. The " late " plots were left undisturbed till the latest date by which the preparation could be completed before the rains, usually about the middle of November. In all cases the trash from the previous crop was burnt on the plots in random heaps and the ash incorporated with the soil.

The results from all experiments showed a small but regular increase in yield from the "early" plots. The increase was usually less than 10 per cent. and was most marked in the case of the maize crops following a cotton crop. There was no difference between the treatments in germination, weight or height of the cotton plants. It was concluded, again without direct evidence, that the slight advantage for " early " cleaning was due to greater accumulation of nitrates in the soil. The advantage was slight, and fields can be prepared at whatever time best suits the available labour, so long as preparation is completed before the rains start.

Digging.—In the main experiment there were three levels of digging : full digging over the whole area, strip digging about 10 inches wide along the planting row, and no digging at all. The digging with a native-type hoe averaged about 4 inches in depth. No yield differences were found until the last year of cultivation in each field, which in both cases was a maize crop. In the black soil field with a very fair mean yield of 2,500 lb. grain per acre the full digging gave a 15 per cent., increase over no digging. In the worn-out soil of the brown soil field with the very low average yield of 700 lb. per acre, the increase was as much as 40 per cent. for the full digging. The strip digging gave an intermediate yield which was not significantly better than no digging.

There were five subsequent experiments concerned with digging. Cotton was planted with three treatments : no digging, normal digging to one hoe depth, and deep digging by trenching. The results were highly significant, no digging and normal digging giving increased yields of 19 per cent. and 13 per cent. over deep digging. The residual effect was tested the following year with maize, and the order of yields was the opposite of that with cotton. There was a progressive increase in yield from no digging, normal digging to deep digging, and the difference only just fell short of significance. Three more experiments with maize and one with groundnuts failed to show any differences.

Maize, therefore, was the only crop which showed any positive response to digging, but the size of the increase was not large enough to pay for the cost of the work involved. From the native point of view increases in yield of the order found can be obtained with less effort by hoeing a slightly larger garden. It was concluded that digging of the land before planting was not necessary except for the first crop after a resting period ; it must be done then to provide a good seed-bed. In all subsequent crops an adequate seed-bed is provided by making up the planting ridges. These conclusions would have to be modified if there were any real pressure on the land.

Early Cleaning of Cotton.—It does not take a profound knowledge of agriculture to realize that young cotton will not thrive when competing with a thick growth of weeds as big as, or bigger than, the cotton plants themselves. Nevertheless every year a large number of cotton gardens can be found with etiolated cotton plants drowned in a sea of weeds. This lack of attention is partly due to lack of interest in the cotton crop, and partly to preoccupation with food crops. But there are some Africans who maintain that the practice is advantageous, the cotton plant being made to grow tall and then quickly making fruiting branches when the grass is removed. The first contention is true, the second is not. Although the results of this experiment were a foregone conclusion, it was thought worth while to find out just how much the crop is decreased by late cleaning.

The figures are so striking that they are quoted in full. One series of plots was cleaned before thinning, and another at the same time as thinning six weeks after planting. The plots were then divided and half had one and half two subsequent cleanings. The yields are expressed as percentages of the normal station practice.

	One cleaning after thinning per cent.	Two cleanings after thinning per cent.	Mean per cent.
Cleaned before thinning	84	100	92
Cleaned at thinning	26	40	33
Mean	55	70	—

A large percentage of the cotton gardens in the central areas of Nyasaland are not cleaned till thinning, and for many this is the only cultivation given. These figures show that the yield is only a quarter to a half of what it might be. The aggregate loss of crop, for want of a few days' work in the early stages of the plants' life, must be very large.

FOOD CROPS

Maize Spacing.—Different varieties of maize have been tried over a number of years. All yellow varieties have been discarded, partly for low yield and partly because the labourers prefer to eat a white maize. Potchefstroom Pearl was grown for some years and was eventually replaced with a selection from the local mixture grown in the vicinity of the Station. This is a hard white type and, though it yielded slightly less than Potchefstroom Pearl, has much better keeping qualities and so is to be preferred. Four spacing experiments were made on this local selection and all led to the same general conclusions. A large number of spacings and numbers of plants per hole were tried, nearly all of them with a fixed inter-row distance of 3 feet. It was found that 2 and 3 feet inter-row spacing was better than 4 or 5 feet, no matter how many plants per hole were left. The 3 feet spacing was slightly better than 2 feet; two plants per hole gave the maximum yield for both 2 and 3 feet spacing, one plant per hole being a good deal worse and three plants slightly lower in yield. All maize on the Station is now planted 3 feet by 3 feet, which is rather wider than is often thought to give maximum yields; less labour per acre is required when planting at 3 feet than at 2 feet. Three seeds per hole are planted and no thinning or supplying is subsequently attempted. This is a labour-saving method which gives very satisfactory yields.

Groundnuts.—These are an important crop on the lake shore, as they are the only leguminous food crop which can be relied on to give a good yield. A large number of varieties have been tried, both bunch and runner types. There is some variation in yield, the best averaging rather more than 1,000 lb. of shelled nuts to the acre, and the worst about 800 lb. Apart from yield considerations it is important to choose a variety which is easy to harvest.

The cost of growing a short ton, excluding all overhead charges, has been about £4.10*s*. Rather more than half of this total represents the cost of stripping the nuts from the plant and shelling with hand labour. With a small seeded runner type from Senegal this part of the cost is at least doubled. Two types have been retained for bulk plantings ; an early bunch variety from Gambia and a semi-bunch variety, Mwitunde, imported from Tanganyika. The latter matures a little later and so labour requirements are more evenly spread out during the harvesting period. It is well known that for high yields and control of rosette disease it is essential to plant early and to space close together. The standard spacing adopted is to plant in two lines on either side of ridges spaced 3 feet apart; the inter row distance on each side of the ridge is 1 foot. This spacing was tried against ridges 1 foot 6 inches apart with seed planted 1 foot apart on top of the ridge, giving the same plant population, but a more even spacing ; and also with 1 foot 6 inch ridges with a double row 1 foot apart, giving double the standard plant density. There was no advantage in the closer ridges with the same population but when the plant density was doubled there was an increase of 210 lb. per acre in a year with the exceptionally high average yield of 1,720 lb. shelled nuts to the acre. In a year of more normal yields it is unlikely that the difference would be so great ; and as the closer spacing requires about 40 lb. more seed to the acre and much more work in preparation, planting and harvesting, it is not justified. It is an advantage to sow two seeds per hole ; if unshelled nuts are planted the germination is slightly delayed and is not quite so good but the final yield is not affected. An experiment was tried with after planting cultivation contrasting clean weeding with hand pulling of the largest weeds only, and really dirty cultivation with no weeding. The last treatment led to a decrease in yields, but there was no difference between the first two. The time of harvest is important with an early-maturing bunch variety which may sprout in the ground ; the optimum time will depend to a certain extent on the season and the amount of moisture in the ground at harvest time. In one experiment with Gambia bunch the highest yield was obtained 105 days after planting ; a week later the yield had dropped 6 per cent. ; a week sooner or two later it had fallen off by 12 per cent. ; and three weeks later the loss was 15 per cent.

Another point of interest with groundnuts is that if two crops are planted in consecutive years, the yield of the second crop is reduced. This was first noticed on a European estate where large areas of groundnuts were being planted by tenant farmers. The first-year yields were good, but they fell off greatly the second year. This reduction of yield might have been due to a variety of causes, but no satisfactory explanation could be advanced until a number of the tenants said that they had always found a second crop to be poor ; they had not mentioned this before planting because they assumed that Europeans knew better. About the same time a large reduction in the yield of groundnuts was found when one crop succeeded another after one intervening crop. The yields are taken from a rotation experiment and are given in the Table below :

Rotation 1.

1st year	..	Cotton : 160 lb. lint
2nd year	..	Cotton : 226 lb. lint
3rd year	..	Maize
4th year	..	Groundnuts : 737 lb. nuts

Rotation 2.

1st year	..	Cotton : 156 lb. lint
2nd year	..	Groundnuts : 776 lb. nuts
3rd year	..	Sorghum
4th year	..	Groundnuts : 374 lb. nuts

It will be noticed that though in the first year the yield of cotton from the two sets of plots was identical, in the fourth the yield was reduced to half when groundnuts succeeded groundnuts. As no reason for this result could be found, a further experiment was laid down. In the final test year of this experiment groundnuts planted in two consecutive years were contrasted with groundnuts with one, two and three other crops intervening. Different intervening crops were tested in the various treatments. The yields are given in the Table below :—

	Shelled nuts per acre lb.
Groundnuts following groundnuts	814
With one intervening crop	915
Mean of plots with two intervening crops	1,054
Mean of plots with three intervening crops	1,035
Significant difference	218

There was no difference between plots in the incidence of rosette or wilt disease, the amount of these diseases being negligible in all cases. It is not usual to plant groundnuts in consecutive years, as it has been found that maize gives an increased yield when following groundnuts. There should be at least two intervening years before the crop is planted again under the conditions which obtain at the Cotton Station.

MAINTENANCE OF FERTILITY

When the Cotton Station was first opened the rotation adopted was three years crop followed by two years rest under pigeon pea. Maize was always the last crop in the rotation and the pigeon pea was sown from four to six weeks after planting the maize. There were signs that this amount of rest would not maintain fertility indefinitely, but there were difficulties in the way of extending the period under pigeon pea. After the first year termites caused a big loss in the pigeon pea, and by the third year there were very few plants left. Also a wilt disease attacked the plants in patches, leaving a very poor stand. About that time Martin drew attention to the beneficial effect of grass on soil structure in Uganda. Elephant grass is not found on the main lake-shore plain, but only alongside the streams which run down from the hills during the rainy season. Every year the dried tops are burnt by bush fires, but the grass is not killed and planting material can always be obtained at the beginning of the wet season, and it has been found that these plantings grow well under field conditions.

A rotation experiment was planned in 1936 to test the suitability of using elephant grass to restore fertility. Various rotations were employed and the main comparisons were between no rest, one year's rest with pigeon pea, two years' rest under either pigeon pea or elephant grass, and three years' rest under elephant grass. Cotton was used in the first test year and maize for the second year. With the cotton crop the last three treatments were all equal and all better than one year or no rest. With the succeeding maize crop the results were rather different. Three years' rest was better than two years, and elephant grass was better than pigeon pea. It was therefore concluded that three years' rest under elephant grass was the minimum required and futher experiments are in progress to find out if four or five years give still better results.

It was thought that the lack of a leguminous crop in the resting period might slow up the restoration of fertility. If very worn-out land is abandoned to bush there is often a very heavy, almost dominant growth of Buffalo Bean (Stizolobium spp.) which becomes less common in later years. It has also been noticed that elephant grass planted on badly run-down soil grows less luxuriantly when planted alone than when mixed with pigeon pea. Accordingly an experiment was planned contrasting elephant grass alone and mixed with velvet bean. No

difference was found in yield when cotton was planted subsequently. The point cannot be said to have been proved, as it was impossible to prevent the growth of buffalo bean among the elephant grass. The seeds of this plant must be capable of lying dormant for at least five years, as they grow up freely even after five years' clean cropping.

The planting and subsequent clearing of elephant grass involves an amount of labour which does not appeal to the African cultivator, so trials are going on to try to find a simpler method of resting the land. Various rest crops have been tried, including pigeon pea, allowed to degenerate into weeds, chance weeds and the local long term sorghum treated as perennial. So far the results have been inconclusive, as no differences have been demonstrated.

Experiments have been made on different spacings and times of planting of the elephant grass, and results show that a wide range of both seem to give equally good results. Spacings have been tried from 3 feet by 3 feet up to 8 feet by 3 feet, and the resulting cover has always been excellent. This is a good deal wider than is reported as being necessary in Uganda to establish a good cover. The local variety of elephant grass is stoloniferous, and after the first year, when growth in Nyasaland appears to be slower than in Uganda, the spread is rapid and all other grasses are largely suppressed. The planting material used is main stems cut up into lengths of about 2 feet 6 inches, pieces bearing roots being preferred. These have been planted from January to early March, not far from the end of the rains, and in all cases a good stand has been obtained. For the time being the standard Station practice is to plant pigeon pea among the maize about the middle of January, when the maize is four to six weeks old. Elephant grass is planted later whenever labour is available, generally during a wet spell when hoeing is impossible. In the first year the elephant grass makes little growth and the pigeon pea gives a crop about September. During the second year the elephant grass makes rapid growth and a second crop can be taken from the pigeon pea if wanted. After that a good deal of the latter dies out with termite attack and is more or less swamped by the vigorous growth of the elephant grass. The year before the land is to be cleared the grass is fired at the end of the dry season, and a fierce fire and a clean burn is the normal result. If this burning is omitted clearing is more troublesome the following year. A strong re-growth is made during the rains and this is cut down in March or April, burnt as soon as dry and the land then dug. Some roots continue to grow during the dry season and these are dug up at intervals. The grass can be burnt at the end of the dry season and the land immediately prepared for planting. But if this is done it is impossible to kill more than a percentage of the roots and a lot of labour is necessary in frequent cleanings of the subsequent crop.

MIXED CROPPING

Mixed or inter-cropping has been tried at various times without success. The very short growing season necessitates the planting of all crops at the break of the rains to get maximum yields, and young plants growing together compete strongly for the available nitrogen. The common haricot bean, which grows well among maize at higher elevations, does not thrive in the hotter climate of the lake shore. If groundnuts are planted among the maize the yield of the latter is not affected, but with a good growth of maize the yield from the groundnuts is so small as to be hardly worth the bother of planting. Similarly groundnuts give a very low yield if planted among rows of cotton, and cleaning the fields is more difficult. If cotton and maize are planted in alternate rows the cotton is so suppressed that the yield is negligible. There is little doubt that for maximum returns crops must be planted in pure stand in this area. Further experiments are being made with planting cotton among wide-spaced maize, not with the idea of increasing cash returns per acre, but to encourage new people to plant cotton among maize because they will obtain a food supply at the same time as they are earning some cash.

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ROTATIONS AND FERTILIZERS

There has only been one experiment with different rotations; the only positive result was that maize yields more when planted after groundnuts than after cotton. In one year the increase was 40 per cent. and another year only 10 per cent. The rotation finally adopted is cotton, maize, cotton, groundnuts and maize, the last being interplanted with rest crops. This rotation is not designed to be suitable for peasant cultivators, but has been adapted to meet the needs of the Station; the chief needs are an adequate acreage of cotton for experimental purposes, and the provision of food crops for the labour force; at the same time the fertility of the soil must be maintained and if possible improved.

This rotation of five years' cropping followed by four years' rest under a mixture of elephant grass and pigeon pea is one which should maintain a good soil structure indefinitely. It also appears that there are enough plant nutrients in the soil to give continuous yields.. Experiments on the use of compost have shown that yield increases are only obtained with uneconomically large dressings. Artificial fertilizers, owing to their high cost and the low value of the crops grown on the Station, have not been considered important. One experiment with artificials was made, but no increases in cotton yield were found, nor were there any residual effects on maize the following year. New fertilizer experiments are being planned, and only the future can prove if the above cropping scheme will maintain yields at their present level. It is hoped, however, that neither artificials nor compost will be needed for a long time to come.

TEMPERATE-ZONE PLANTS IN THE TROPICS*

The success or failure of temperate-zone plants transferred to the tropics-blackberry, Boysenberry, corn, grape, plum, raspberry, tomato, Youngberry and others have been tried—is controlled not only by disease, humidity and temperature, but also (in many cases) by the shorter day-length and absence of cold-dormancy there.

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INTRODUCTION.

FROM the viewpoint of the temperate zones, agriculture in the tropics may appear radically different and apart from that of the cooler latitudes. In certain respects this is so, though not to the degree that might popularly be supposed. Actually results show a suprising and deep-seated interdependence between the agricultures of temperate and torrid regions. The circumstances that limit crop production whether in North America, Europe or Asia, are not of significance only to those regions. A tomato or a bean, for example, that will resist humidity and disease in the tropics may prove economic value throughout the world. For best progress in agriculture it is essential that we consider crop problems in a universal manner. It is only a few important crops that we can confine our interests strictly to the temperate or to the tropic zone. Such climatic differences in the final analysis reduce to little more than a combination of the variables heat, light and humidity, most of which can be, and often are, experienced in any one environment.

In this view, a cultural or pathological problem—let us say of potatoes, cotton or beans in South America—or, better still, a resistant selection or probable economic or scientific value cannot be limited in importance by geography or climate. The value to humanity is about the only real determinator.

The phenomena associated with reaction of temperate climate plants to tropical environments are matters of broad economic importance. To large sections of the world they have a direct bearing on nutrition and human welfare, since for many cool-climate food crops there are no acceptable substitutes that show good or better adaptability to torrid conditions. To understand the natural influences that lead to success or failure would be to make a full step forward in the over-all problem.

In analyzing the reaction of plants, when placed under any different environment, five fundamental influences should be considered : temperature ; duration and intensity of light ; humidity ; diseases and insects ; and soil. These singly or in combination control the crops' adaptability. Furthermore, it makes a little difference whether we are considering garden vegetables, field crops or even such woody perennials as the tung-oil tree, plums, apples or grapes. It is their response to these five influences that will determine the ultimate degree of success or failure.

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Before we consider the matter in more detail it might be well to draw a clear distinction between annual and woody perennial plants. The environmental problems of each must be considered apart. The former are concerned only with circumstances that influence the growing period, while the latter have all of this in addition to a sensative and most important dormant season to be acted upon. With such perennials usually it is this rest period that proves to be the most deciding factor.

SEASONAL INFLUENCES.

During the growing season, whether with annuals or perennials, results indicate that the most controlling limitations imposed upon temperate climate plants in tropical regions are, broadly speaking, in approximately this relative order : diseases and insects ; short light (day) periods of usually high intensity ; excess or insufficient moisture ; and, of course, in some cases, above-optimum temperatures.

By contrast, with woody perennials the important circumstance or the dormant season is largely a matter of temperature. Practically all temperate plants, by reason of their nativity to regions with cold winters, have what is generally termed a " chilling requirement ", that is to say, a certain amount of exposure to low winter temperature, usually 40°F. or below, which is required as an aid to the physiological process that must precede the beginning of new spring growth. Without this, various signs of poor adaptability are manifest, as will be seen in more detail further on.

The question of whether the species is native to a humid or arid climate likewise is of importance. When types indigenous to dry regions are planted in rainy or humid sections results are apt to be no more favourable than if in the reverse case. We have ample proof of this through the innumerable vain attempts to grow European grape in humid, southern United States, or the fiasco of the date palm when planted in the humid tropics.

Still another distinction should be observed within the group of tropical plants. Species from medium and high altitudes constitute a classification somewhat distinct from both the low-land tropical and the purely temperate. Several of the annuals or non-woody perennials of this group are among our most important economic crops, as the tomato and potato. When grown as annuals selected forms of these prosper in the temperate zone summers where growing conditions approximate that of their high altitude native habitat. On the other hand, if they are planted farther down the mountain in the tropical lowlands serious cultural problems often arise. The slight changes in temperatures often alter such climatic matters as rainfall, air humidity and, less directly, disease and insect attacks and even soil fertility. The entire ecology is changed.

VARIED RESPONSE OF ANNUAL CROPS.

The tomato affords a good example of an economically important plant that gives varied response to seemingly slight differences in environment. Depsite the fact that it is of tropical (medium high altitude) origin, it has proven to be one of the most needed and difficult food plants to produce throughout the lowland tropics. The reasons are not simple, as will be seen.

Recently the author had the opportunity to inspect tomato plantings through a large part of the Republic of Venezuela, where, incidentally production problems are unusually severe. The same well known northern varieties were planted in all locations. In the environs of Caracas (300,000 population) production has been unusually difficult, due principally to attacks of mildew, *Phytophthora infestans*. When we check the prevailing temperatures and humidity and compare these with our own results in the moist highlands of Costa Rica, or with the recently hard-hit tomato-growing sections of north-eastern United States, a significant variety-climate orrelation begins to take form.

In regions having roughly the same humidity and seasonal effects—but at some 2,000 feet lower elevation and consequently with higher temperatures—an entirely different situation was observed. At the Pampanito Experiment Station near Trujillo, Venezuela, tomato plantings were being destroyed by nail-head "rust" (*Alternaria solani*). No evidence of mildew could be found.

In other parts of the country where temperature may have been high or relative humidity too low for either of these problems, certain virus diseases were the important limitation. In still other localities, soil-carried organisms, as the various wilts, were serious.

When we compare these observations with results on other tropical or temperate regions where the limitations may be due to any of these difficulties or to leaf mold (*Cladosporium*), leaf spot (*Septoria*), various fruit rots, flower drop or poor growth, the power of climate over variety becomes apparent. Moreover, it is something that cannot be overlooked if success is expected.

It will have been noted, no doubt, that no consideration was given to the effects of day length (photoperiodism) in these tomato experiments. Though there is some slight indication that photoperiodic requirements may vary as between northern developed varieties and tropical sorts, this scarcely could be viewed as a major consideration in the present case, since latitude differed little and varieties planted were the same.

When strictly temperature climate vegetables—as the onion or northern sweet corn—were planted in tropical Costa Rica, a marked demonstration of the effects of photoperiodism was evident. The relatively short days of this near equitorial location typically kept the onion in a state of continuous vegetative growth during most of the year which usually prevented formation of sizable bulbs. This situation has been reported by other workers in various sections of the tropics. In our Costa Rica experiments, only during the period of longest day lengths, May to July, was any appreciable proportion of bulbs formed by most varieties. During other seasons a slowly debilitating foliage growth was continuous.

The action of day length on the northern corn varieties gave quite the opposite effect. In this case, the relatively short day periods reduced vegetative action, usually bringing the plant into tassel at from one to three feet in height.

Indications are that many northern climatic perennial plants may in similar manner be seriously restricted in growth or, on the other hand, be stimulated into excessive or prolonged vegetative action, as was the onion.

When we inspect the effect of short day lengths on the sweet potato in the tropics, as compared to that of longer ones in the central United States, we see beneficial results. Generally with a given variety more tubers are produced in comparison to vine growth in tropical lattitudes, and sugar content is apt to be higher. This is understandable, since the sweet potato is of tropical origin.

Conversely indications are that relatively shorter tropical day periods may restrict sugar development in certain temperate climate plants, as garden beets, strawberries and northern bush or tree fruits. These kinds in general are less sweet to taste in the tropics than when grown in higher latitudes, irrespectively of temperatures or humidity.

Excess rainfall has led to the other problems with such warm climate plants as sorghums and peanuts. Most United States varieties of sorghum that we have tested in Costa Rica, especially those with compact heads were seriously attacked by molds and rots, and the seeds sprouted in the head before harvest if grown during the rainy season. Peanuts, likewise, frequently sprouted before the harvest if caught in a period of very rainy weather.

In making a variety-climate correlation a few most important points of determination might be these : (*a*) does the variety require a winter or dormant-season chill and, if so, can the environment in question satisfy this need ; (*b*) is the variety suited to the prevailing temperatures for the growing season ; (*c*) is the humidity and rainfall ample or excessive for the variety ; if excessive, will it resist the diseases or prosper in the soil as influenced by such conditions; (*d*) is the variety adapted to the day lengths or light periods of the latitude in question, or the amount and strength of sunlight, as determined by more localized conditions ; (*e*) it is equal to whatever other natural circumstances or limitations of region might influence success.

No doubt a few of these questions might best be answered through actual trial, though, for the majority, there is need for little more than a comparison of the climates of the proposed and native environments.

One of the first questions popularly asked when temperate climate plants fail in the tropics is : what about the soil or the cultural practices ? Seldom have we inquired of the climate, or of the plants' adaptability to it.

Soil and cultural practices are important, of course, though usually in a secondary way to the more fundamental matter of climatic adaptability. Lacking this, it is mostly a losing fight, irrespective of all other modifying circumstances.

IMPROVEMENT POSSIBLE WITH PROPER APPROACH.

To peoples of the tropics the prospects would appear discouraging for many desired and much needed food plants were it not for the well demonstrated science of genetics and plant breeding. Through this and with a methodical approach, almost any desired end is possible. Nevertheless we often are compelled to expend greater immediate labours than was the case for crop improvement in the temperate zones. Our end results, however, may come faster.

When better apples, grapes, wheat or cabbages were desired in Europe or North America the important considerations mostly were for better quality, higher production or disease resistance. Oft times relatively minor variables of climate were considered, though, since all parent materia was native to medium or higher latitudes with cool or cold winters—there was no problem of harmonizing radically different factors of climatic adaptablity. More complex is our problem in the tropics.

In any outline for a new and better crop variety for warm climate production, generally speaking, stronger resistance to disease and insects, as well as to extremes of drought, moisture and heat must be considered. If we are compelled to inter-breed temperate with tropical kinds, these problems are multiplied severalfold. In the progeny selection consideration to more factors must be given, and of course, the percentage of good to bad in the hybrid populations will be much smaller.

In this way immediate gains might appear to come more slowly, though we have the advantage of availability to the improvement program of certain plant genes for superior quality ; varieties brought to their present high development through the many years of tedious progress in temperate agriculture. When these factors for superior quality are combined with others native to the tropics for better adaptability, considerable improvement can be expected in tropical agriculture. Relatively speaking, this is a field just beginning to unfold.

VALUE TO TEMPERATE AND TROPICAL REGIONS.

In agriculture the world over there is the tendency for over-specialization at the expense of broader interpretations. Great emphasis and study often have been placed on some detailed and localized problem which allowed proportionately little thought for the wider ramifications it might have with distant plant relationships and climates. With this strict and even short-

sighted approach we may struggle over some question of plant culture or improvement, wherein if with a more universal understanding, even at the expense of some degree of specialization, the problem might be vastly simplified. In short, the end progress would most assuredly be greater.

Throughout the years plant science has laboured in great detail and at much expense to acclimatize or to control disease on many important crops. Well and good, but had a due proportion of this effort been devoted toward comprehending and charting the vast world reservoir of already acclimatized and disease-resistant breeding material many short-cuts and perhaps more rapid progress might have been possible. The admirable work of Reddick in giving blight resistance to the common potato from an obscure related species wild in Central America is an example of this.

It is understandable, of course, that no one research worker in the temperate zone or in the tropics, can be expected to know the full potentialities of useful plant breeding material throughout the world. The job is far too tremendous for any one individual. What is needed and would seem to be feasible is a better co-ordination and interchange of knowledge and appreciation of connected problems on the part of plant research workers everywhere. A closer tie-up between temperate zones and the tropics is an especial need.

Plant improvement in the tropics can have pronounced value to temperate crop production. From certain viewpoints these warmer regions might be looked upon as an outdoor workshop where genetic, pathological and physological problems can be studied more effectively and where all year growing conditions often allow a saving of more than half the costly time requirement in long term breeding programmes. When well developed and closely synchronized with its temperate zone equivalent, plant research in the tropics undoubtedly will become of vast significance to world-wide agriculture.

PLIGHT OF TEMPERATE WOODY PERENNIALS.

The plum, the grape and the blackberry offer good examples of woody temperate climate plants that time and again have been tested experimentally in the torrid zone. The fact that they have almost consistently failed affords some interesting sidelights on the subject. The reasons for these failures, in a broader sense might be attributed to something in the following relative order: (*a*) insufficient cold or chill during the dormant period; (*b*) diseases during growing period; (*c*) relatively short tropical day lengths. In the final analysis the lack of a cold dormant season would seem to be the one most overpowering influences that prevents satisfactory production of most temperate climate woody perennials in the lowland tropics.

With a few warm—temperate species—those that are indigenous to somewhat intermediate latitudes and dry climates, as the fig, the olive and the European grape—diseases may prove a greater limitation than lack of winter chill. It might be stated more clearly this way: with woody plants native to cold temperate climates, winter chill is the most dominating influence for success. Without this they are worthless. With species native to the dryer and warmer temperate countries, diseases may prove an equal or even greater limitation than lack of dormant-chill.

It might be desirable to view in some detail the results shown by a few actual experiments. When good nursery stock of the Abundance plum, a Japanese variety, was planted at Turrialba, Costa Rica, the first season's growth was unusually vigorous. By October the trees had grown to a height of eight or nine feet, having made unusually long and vigorous switches, well supplied with healthy foliage. By December they were yet lush with tender growth and many leaves, while, by contrast, nearby plants of a wild sub-tropical species (*Prunus umbellata*) from southern Florida were then practically leafless in a natural dormancy.

By the following April the wild Florida plum was again verdant with new spring foliage, though the more nothern Japanese varity continued with its leaves of the previous season and by then was showing definite signs of fatigue.

By the following January, two years after planting, the wild Florida plum was once more leafless in a more or less normal dormant period. The Japanese cultivated sort by this time had become obviously sick.

Within three years from time of planting the Abundance variety was in an exhausted state of health, mostly dormant though partly verdant, during all seasons; there was no appreciable difference in growth stage, winter or summer. Limbs or switches, once leafless, failed to put forth new growths or new leaves. Vigorous new growths came only from near the crown, or ground level, giving evidence of a starved or otherwise growth-inhibiting condition of upper plant parts. This is a situation commonly seen with temperate climate woody plants in the tropics and one that mostly can be taken to indicate insufficient chilling and consequent poor adaptability.

The wild Florida species had become completely leafless by December. From January to March a profusion of flowers was produced, and by April the plants were covered with a new cloak of leaves. No water sprouts had grown from lower regions. As compared to scarcely a 15 per cent. adaptability for the more northern cultivated variety, this wild southern species indicated no less than 85 per cent. adaptablity to lowland tropical conditions.

When the North American cultivated grapes, as Concord Caco, Champion, Lutie and Niagara, were planted at Turrialba, Costa Rica, growth typically was arrested by premature or mid-summer dormancy. The same need for winter chilling, as seen with the cultivated plum, was evident here. There was the same tendency for production of basal water sprouts and failure of upper plant parts to bud out after once becoming fully dormant.

Three years from planting, these temperate climate cultivated varieties at Turrialba were puny and sick. From a total of 46 plants in 12 varieties, European and American, only two had produced fruit. This was small in quantity and poor in quality.

In the same vineyard wild vines of identical age from Central America and southern Florida, together with improved hybrids of these, grew in full luxuriance, often producing as many as 50 or more fruit clusters. Also these native tropical kinds usually showed a more nearly normal sweetness of fruit.

Experiments with raspberries and blackberries have given interesting results. In a mixed planting of tropical wild kinds and temperate cultivated sorts of Turrialba, Costa Rica, the need for winter chill with the northern varieties was evident.

The Latham red raspberry, after making moderately good growth the first year, failed to bud out the following spring from fully dormant canes—all good growths coming from near the crown, as was the case with the northern plums and grapes. After two years of steadily decreasing vigour, all plants of this variety were dead. Three black-cap varieties gave nearly similar results, though persisted a few years longer.

The popular Boysenberry and Youngberry of the Southern United States, after making each year luxuriant and relatively disease-free growth, failed to bud out in the spring from upper buds of mature canes, thus giving no flowers or fruit.

In contrast to these poor results with the temperate varieties, several medium elevation tropical species, *e.g.*, *Rubus trichomallus* and *R. rosiaefolius*, though in some cases much more attacked by disease, gave heavy fruit crops under indentical cultural conditions.

Still different reactions were observed with the tropical high-elevation raspberry *R. glaucus* and the sub-tropical lowlands dewberry, *R. okeechobeus*, neither of which indicated need for dormant chill nor longer day lengths. During average years both species made excessive vegetative growth, though they produced few flowers. When the seasons were unnaturally dry, the *okeechobee* dewberry flowered heavily.

Observations lead to the belief that meagre fruit production obtained from these latter kinds was due in large part to growth conditions being overly favourable. In their native habitats this excess growth is prevented by cool temperatures with the highland raspberry and by poor soil and droughty conditions with the lowland dewberry. Lacking these controls both species tend to over indulge in riotous vegetative living.

CLIMATE-VARIETY CORRELATION IMPORTANCE.

All too frequently there is the tendency to ignore, or at least underestimate, the importance of climate in tropical agriculture. The frequent and almost indiscriminate " hopeful " planting of cold climate perennial varieties in tropical regions gives evidence of this. In the reverse case it would be scarcely conceiveable that anyone would expect success from banana, mango, pineapple or any of the torrid zone crops if planted out of doors on the colder side of latitude forty. Presumably no one would so much as try it. By what right then should we expect favourable results when plants, native to these colder regions, are brought to the tropics.

In agriculture, whether in the colder sections or on the equator, it is seen that the most powerful influence controlling the end result is the combination of temperature, humidity and light we popularly term climate. Even soil fertility, disease and insect attacks—in part at least—are a result of this influence. For best success a crop variety should be correlated closely in respect to cultural requirements with these forces. That is to say, it should have whatever genetic characteristics are necessary for it to prosper under the environmental conditions imposed. Whenever we have chosen to lunge forth without heed to these matters, disappointment has been the unfailing result.

COCONUT RESEARCH SCHEME (CEYLON)

BOARD OF MANAGEMENT

DRAFT MINUTES OF THE NINETY-FIFTH MEETING OF THE BOARD OF MANAGEMENT, COCONUT RESEARCH SCHEME, HELD AT 10 A.M. ON SATURDAY, SEPTEMBER 4, 1948, IN THE CIRCUIT BANGALOW, RATMALAGARA ESTATE, MADAMPE.

Present.—(1) D. Rhind, Esq. (Director of Agriculture), Chairman; (2) H. E. Peries, Esq., C.C.S. (Acting Deputy Secretary to the Treasury); (3) E. Muttukumaru, Esq. (Representing the P.A. of Ceylon); (4) Col. W. G. Mack, O.B.E., E.D. (Representing the P.A. of Ceylon); (5) C. E. L. de Silva, Esq. (Representing the L.C.P.A. of Ceylon); (6) A. N. D. A. Abeysinghe, Esq. (Representing the L.C.P.A. of Ceylon); (7) Graham Panditteseker a, Esq., J.P., U.M. (Representing the small holders); (8) D. D. Karunaratne, Esq., M.P. (Representing the small holders); (9) Albert F. Peries, Esq., J.P., U.M., M.P. (Representing the House of Parliament); (10) N. H. Kirtheratne, M.P. (Representing the House of Parliament).

Dr. Reginald Child, (Director, C.R.S.); Mr. S. C. Kahawita (Secretary).

Apology for absence was received from Mr. H. W. Amarasuriya, M.P.

1. MINUTES

The minutes of the previous meeting held on Saturday, July 17, 1948, which had been circulated were confirmed without amendment.

2. CORRESPONDENCE

(*a*) A letter from the Agricultural Adviser to the Commissioner General in South-East Asia, Dr. H. W. Jack, who recently paid a visit to the Headquarters of the Coconut Research Scheme, was tabled. In the letter Dr. Jack wrote, " Once again I would like to express my great pleasure in being able to visit your Institute recently and in getting a first hand knowledge of the very excellent work that is being done in the Coconut Industry of Ceylon.

I only hope the people will respond to your efforts and act on your practical advice which is now available from your researches, and the Government will continue to support you in every way."

(*b*) A request from the Secretary of the Indian Central Coconut Committee for the use of blocks of certain photographs in the " Illustrated Guide to Coconuts " was placed before the Board, who raised no objection.

(*c*) The Chairman informed the Board that the Hon. the Minister for Agriculture and Lands accompanied by the Permanent Secretary would be visiting the Headquarters of the Coconut Research Scheme on September 14, 1948, at 9·30 A.M. The Director said that he would invite the Hon. the Minister also to visit Ratmalagara estate, on his way to Puttalam.

3. BOARD OF MANAGEMENT

The Chairman reported that Mr. H. E. Peries, C.C.S., had been appointed as the Treasury Representative, in place of Mr. T. D. Perera, C.C.S., who is now acting as Secretary to the Treasury.

4. SUB-COMMITTEES

(*a*) *Research Policy.*—Minutes of the 1st meeting of the Sub-Committee to report on the Industrial side of the Scheme's Research Policy, which had been circulated were considered and authorized the Director to implement the following recommendations :—

(i.) The appointment of a Graduate Research Assistant to the Technological Chemist.

(ii.) The present Research Assistant to the Technological Chemist, (Mr. M. R. N. Nathanael, B.Sc. (Lond.), should be sent to England in 1949 for at least 2 years post-graduate studies with a view to higher qualifications.

(*b*) *Buildings.*—The minutes of the 31st Buildings Sub-Committee Meeting which had been circulated were tabled. The Board ratified the decision to call for tenders and the suggested alteration to the final drawings.

5. ESTATES

(*a*) The Estates Sub-Committee to which the report on the Estates had been referred to decided to hold their next meeting on September 22, 1948, at 10.30 A.M. at Bandirippuwa estate.

6. FINANCE

(*a*) *Printing.*—The Board authorized the printing of 5,000 copies of the 14 Sinhalese leaflets in the form of a booklet at a cost not more than Rs. 2,500. These booklets to be distributed free to the members of Co-operative Societies and charged to the rehabilitation account.

7. REHABILITATION

Director supplied the following information on work in relation to Co-operative Societies.

(*a*) *Sandalankawa Nursery.*—A nursery attached to the Sandalankawa Coconut Producers' Co-operative Sales Society, Ltd., has been established with 6,998 seednuts at a cost of Rs. 2,621·82 (including cost of seednuts). This was approved.

(*b*) *Supply of Planting Material.*—200 Grade 1 seedlings to each of the Coconut Producers' Co-operative Societies, Udabaddawa and Nattandiya, have been issued free of costs. The costs of these have been credited to the nursery working account and debited to the Rehabilitation account. This was ratified by the Board.

(*c*) *Issue of Publications.*—A circular letter in Sinhalese together with a sample collection of Sinhalese publications was addressed to the Secretaries of the 25 Coconut Producers' Co-operative Sales Societies in the N.-W. P. on July 15, 1948, requesting them to write in their requirements of publications, for distribution among their members. Up to date, September 3, 1948, only 7 Societies have replied and their requirements (totalling 414 sets of leaflets), have been supplied.

The meeting terminated at 12.45 P.M. with a vote of thanks to the Chair.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED JULY 31, 1948

Province	Disease	Fresh cases during the month	Cases up to date since Jan. 1, 1948	From Jan. 1, 1948, to July 31, 1948			
				Deaths	Recoveries	Balance ill	No. shot
Western Province	Foot-and-mouth	—	8	—	8	—	—
	Rabies	—	1	1	—	—	—
Colombo Municipality	Foot-and-mouth	—	307	—	307	—	—
	Rabies	9	44	—	—	—	44
Cattle Quarantine Station, Colombo	Anthrax	18	25	25	—	—	—
Northern Province	Black Quarter	—	9	9	—	—	—
	Rabies	—	1	—	—	—	1
	Foot-and-mouth	—	2	1	1	—	—
North-Western Province	Mange in goats	—	16	—	16	—	—
North-Central Province	Foot-and-mouth	—	567	10	557	—	—
Sabaragamuwa Province	Foot-and-mouth	98	558	13	519	26	—
Southern Province	Foot-and-mouth	—	760	24	736	—	—
	Rabies	—	3	3	—	—	—
Central Province	Rabies	13	16	13	—	—	3
	Piroplasmosis	—	1	—	1	—	—
	Foot-and-mouth	13	13	—	9	4	—
Uva Province	Foot-and-mouth	2	107	—	101	6	—
	Rabies	1	3	1	—	—	2
	Piroplasmosis	1	1	—	—	1	—

T. M. Z. MAHAMOOTH,
Deputy Director (Animal Husbandry),
and Government Veterinary Surgeon.

Peradeniya, August 30, 1948.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED AUGUST 31, 1948

Province	Disease	Fresh Cases during the month	Cases up to date since Jan. 1, 1948	From Jan. 1, 1948, to Aug. 31, 1948.			
				Deaths	Recoveries	Balance Ill	Number Shot.
Western Province	Foot-and-mouth	—	8	—	8	—	—
	Rabies	—	1	1	—	—	—
Colombo Municipality	Foot-and-mouth	—	307	—	307	—	—
	Rabies	8	52	—	—	—	52
Colombo Cattle Quarantine Station	Anthrax	—	25	25	—	—	—
Northern Province	Black Quarter	—	9	9	—	—	—
	Rabies	1	2	—	—	—	2
	Foot-and-mouth	250	252	101	131	20	—
North-Western Province	Mange in goats	—	16	—	16	—	—
North-Central Province	Foot-and-mouth	—	567	10	557	—	—
Sabaragamuwa Province	Foot-and-mouth	—	558	13	545	—	—
Southern Province	Anthrax	5	5	5	—	—	—
	Foot-and-mouth	—	760	24	736	—	—
	Rabies	—	3	3	—	—	—
	Black Quarter	4	4	3	1	—	—
Central Province	Rabies	—	16	13	—	—	3
	Piroplasmosis	—	1	—	1	—	—
	Foot-and-mouth	8	21	—	21	—	—
Uva Province	Foot-and-mouth	2	109	—	109	—	—
	Rabies	—	3	1	—	—	2
	Piroplasmosis	—	1	—	1	—	—

T. M. Z. MAHAMOOTH,
Deputy Director (Animal Husbandry) and
Government Veterinary Surgeon.

Peradeniya, October 1, 1948.

ANIMAL DISEASE RETURN FOR THE MONTH ENDED SEPTEMBER 30, 1948

Province	Disease	Fresh Cases during the month	Cases up to date since Jan. 1, 1948	From Jan. 1, 1948, to Sept. 30, 1948. Deaths	Recoveries	Balance Ill	No. shot.
Western Province	Foot-and-mouth	—	8	—	8	—	—
	Rabies	—	1	1	—	—	—
Colombo Municipality	Foot-and-mouth	—	307	—	307	—	—
	Rabies	10	62	—	—	—	62
Colombo Cattle Quarantine Station	Anthrax	6	31	31	—	—	—
Northern Province	Black Quarter	—	9	9	—	—	—
	Rabies	—	2	—	—	—	2
	Foot & Mouth	300	552	*320	232	—	—
Sabaragamuwa Province	Foot-and-mouth	—	558	13	545	—	—
North-Western Province	Mange in goats	—	16	—	16	—	—
North-Central Province	Foot-and-mouth	—	567	10	557	—	—
Southern Province	Anthrex	—	5	5	—	—	—
	Food and mouth	—	760	24	736	—	—
	Rabies	—	3	3	—	—	—
	Black Quarter	—	4	3	1	—	—
Central Province	Rabies	—	16	13	—	—	3
	Piroplasmosis	—	1	—	1	—	—
	Foot-and-mouth	—	21	—	21	—	—
Uva Province	Food and mouth	—	109	—	109	—	—
	Rabies	—	3	1	—	—	2
	Piroplasmosis	—	1	—	1	—	—

* Death rate was high on account of the severe drought which was prevailing in Delft Island.

T. M. Z. MAHAMOOTH,
Deputy Director (Animal Husbandry), and
Government Veterinary Surgeon.

Peradeniya, November 1, 1948.

METEOROLOGICAL REPORT, JULY, 1948

STATION	TEMPERATURE				HUMIDITY		Amount of Cloud	RAINFALL		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Minimum)		Amount	No. of Rainy Days	Offset
	°	°	°	°	%	%		Ins.		Ins.
Agalawatta	86·0	+0·9	73·1	—0·6	83	98	7·9	6·00	25	—6·70
Anuradhapura	92·9	+2·1	76·9	+1·0	63	84	7·6	0·03	1	—1·29
Badulla	86·2	—0·2	64·7	+0·7	69	94	5·0	3·46	9	+1·29
Batticaloa	92·4	+0·1	77·4	+0·4	66	78	7·2	1·67	5	+0·63
Colombo	85·0	+0·2	77·2	+0·1	82	89	7·4	2·70	16	—2·79
Diyatalawa	78·1	—0·1	62·8	+0·2	65	81	4·8	1·63	8	—0·33
Galle	83·0	+0·2	77·0	+0·1	87	88	6·0	3·64	15	—2·70
Hakgala	67·6	—0.7	58·0	+0·5	86	89	7·9	6·94	15	+0·30
Hambantota	85·9	—1·8	75·5	—0·9	83	93	7·8	0·09	2	—1·92
Jaffna	86·5	+0·4	80·2	+0·4	80	85	6·4	0	0	—0·55
Kandy	82·6	—0·2	71·2	+0·6	80	88	7·8	8·17	27	+0·85
Kurunegala	86·2	—0·2	75·7	+0·4	78	88	6·9	3·82	26	—0·06
Lunuwila	85·0	—0·2	77·6	+0·6	82	86	8·3	1·47	15	—2·55
Mannar	87·2	—0·3	79·5	+0·4	78	85	6·2	0·01	1	—0·34
Nuwara Eliya	65·1	—0·3	55·5	+0·7	89	91	9·0	10·57	25	—0·45
Puttalam	86·5	+0·6	79·0	+0·7	77	82	6·4	0·12	1	—0·87
Ratnapura	86·4	—0·3	74·4	—0·2	82	93	8·2	10·53	24	—2·24
Talawakele	69·4	—0·8	60·2	+0·7	92	97	9·3	14·99	30	+1·69
Trincomalee	94·2	+1·8	78·6	+0·5	68	80	6·4	0·22	3	—1·51

Rainfall in July was, on the whole, above normal among and to the east of the central hills, and below normal elsewhere. The larger excesses (of the order of 5 to10 inches) occurred immediately to the east of the hills, the highest being 7·67 inches at Horaborawewa, 7·34 inches at Kudawewa and 7·14 inches at Alutnuwara. The larger deficits were found in the south-western low-country and included 9·27 inches at Udugama, 7·03 inches at Opata and 6·70 inches at Agalawatta.

As usual for this time of year the rainfall was heaviest on the south-western slopes of the hills, several stations recording totals over 25 inches. The largest monthly aggregates were 36·24 inches at Norton Bridge, 32·56 inches at Watawala and 31·62 inches at Blackwater Estate. Rainfall decreased gradually towards the north and the east, butl ncreased again on the north-eastern slopes of the hills. There was very little rain in the northern half of the Island, a number of stations sending in nil reports.

Only two daily falls of five inches or over were reported in July, 5·47 inches at Norton Bridge and 5·14 inches at Watawala, both on the 4th.

The weather during the month was predominantly of the south-west monsoon type, with rain generally confined to the south-west quarter.

Temperatures were about average by day, and a little above average by night. The highest recorded shade temperature for the month was 97·5 at Trincomalee on the 21st, other outstanding temperatures being 97·3° at Batticaloa on the 29th and 97·2° at Anuradhapura on the 30th and 31st. The lowest air temperature was 52·3° at Nuwara Eliya on the 23rd. Humidities were generally above average, particularly by day. Winds were south-westerly.

D. T. E. DASSANAYAKE,
Superintendent Observatory.

METEOROLOGICAL REPORT, AUGUST, 1948

STATION	TEMPERATURE				HUMIDITY		Amount of Cloud	RAINFALL		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Minimum)		Amount	No. of Rainy Days	Offset
	°	°	°	°	%	%		Ins.		Ins.
Agalawatta	85·8	+0·8	72·3	—1·3	78	98	7·7	9·19	17	— 1·85
Anuradhapura	89·8	—1·5	76·1	+0·6	68	86	7·0	3·45	3	+ 1·83
Badulla	86·0	—0·1	64·3	—0·1	64	91	5·1	1·45	3	— 1·75
Batticaloa	91·9	+1·4	77·1	+0·6	66	78	7·8	1·58	3	— 0·37
Colombo	84·7	—0·1	77·0	+0·1	81	88	7·2	6·60	12	+ 2·57
Diyatalawa	77·2	—0·7	63·1	+1·4	65	76	5·0	2·92	6	— 0·20
Galle	82·5	—0·1	76·4	—0·3	87	88	5·6	6·15	17	+ 0·01
Hakgala	66·9	—2·3	57·9	+0·6	83	89	7·0	0·98	6	— 4·17
Hambantota	88·5	+1·6	76·4	+0·3	77	88	9·5	1·15	6	— 0·29
Jaffna	86·3	+0·4	80·2	+1·0	77	82	7·5	1·34	3	+ 0·23
Kandy	83·3	+0·2	71·5	+1·5	76	85	7·6	4·74	23	— 0·99
Kurunegala	86·4	—0·5	75·5	+0·7	77	86	7·4	6·21	16	+ 2·59
Lunuwila	84·6	—0·6	77·1	+0·3	81	86	7·9	7·50	9	+ 4·31
Mannar	86·5	—0·9	78·8	+0·2	78	84	6·8	1·96	1	+ 1·30
Nuwara Eliya	65·2	—0·9	55·5	+1·3	86	88	9·2	2·92	23	— 4·59
Puttalam	85·3	—1·0	77·8	—0·1	80	86	6·2	2·16	5	+ 1·51
Ratnapura	87·0	+0·4	74·9	+0·7	78	93	8·8	9·49	26	— 1·90
Talawakele	70·3	—0·6	60·1	+0·9	87	94	8·4	5·13	28	— 4·95
Trincomalee	93·1	+1·1	78·2	+0·9	64	80	7·1	2·40	4	— 1·21

Rainfall in August was below normal over a major portion of the Island, excesses being more or less confined to the north-west quarter, where Maha Uswewa recorded 6·65 inches above average, and Galawela and Berna Estate, 6·46 inches and 6·29 inches above their respective averages. The larger deficits (of the order of 5 to 10 inches) occurred on the south-western slopes of the hills, the highest being 13·57 inches at Norton Bridge, 10·76 inches at Watawala and 9·65 inches at Kenilworth Estate.

The largest totals were experienced on the south-western slopes of the hills, where several stations received over 10 inches, *e.g.*, 15·86 inches at Kenilworth Estate, 15·45 inches at Kellie Estate and 15·31 inches at Theydon Bois Estate. Rainfall decreased towards the north and the east, the monthly totals to north of Anuradhapura and to east of the central hills being generally below 2 inches. Several stations in these regions received no rain at all.

There were five daily falls of 5 inches or over in August, the highest being 5·75 inches at Mayfair Estate on the 1st.

Temperature departures from normal were generally small, being on the whole slightly negative by day and a little above average by night. The highest recorded shade temperature was 97·8° at Trincomalee on the 16th, while the lowest air temperature was 52·9° at Nuwara Eliya on the 31st. Humidities were mainly above average. The prevailing winds were south-westerly.

D. T. E. DASSANAYAKE,
Superintendent Observatory.

METEOROLOGICAL REPORT, SEPTEMBER, 1948

STATION	TEMPERATURE				HUMIDITY		Amount of Cloud	RAINFALL		
	Mean Maximum	Offset	Mean Minimum	Offset	Day	Night (from Minimum)		Amount	No. of Rainy Days	Offset
	°	°	°	°	%	%		Ins.		Ins.
Agalawatta	85·8	+0·3	71·8	—1·4	80	98	7·2	14·94	24	— 3·82
Anuradhapura	93·1	+1·6	76·0	+1·0	62	84	7·0	0	0	— 9·72
Badulla	87·0	+1·3	63·5	—0·7	58	91	4·8	1·12	2	— 7·77
Batticaloa	90·2	+0·5	77·0	+0·9	69	78	7·4	0·26	2	— 6·93
Colombo	86·3	+1·0	76·5	—0·1	76	88	6·8	2·18	14	—11·53
Diyatalawa	78·1	+0·2	60·3	—0·6	65	83	6·2	2·67	5	— 6·51
Galle	83·1	+0·2	76·8	0	84	88	6·4	7·53	22	— 4·52
Hakgala	70·3	+0·3	57·7	+0·9	77	83	6·8	3·98	6	— 7·30
Hambantota	86·5	—0·1	76·6	+0·5	82	88	7·6	2·54	9	— 2·22
Jaffna	86·7	+0·6	80·0	+0·9	79	82	6·8	0·22	1	— 8·98
Kandy	85·9	+1·6	69·2	0	70	87	6·7	2·12	10	— 8·42
Kurunegala	89·3	+1·7	75·0	+0·7	68	86	5·4	0·84	9	—14·02
Lunuwila	86·3	+0·4	76·5	+0·3	77	88	6·6	1·36	12	— 9·53
Mannar	87·4	—0·3	79·4	+0·7	77	82	6·6	0	0	— 6·58
Nuwara Eliya	67·8	+1·0	52·2	—0·9	80	91	7·6	2·37	16	— 7·39
Puttalam	86·8	0	79·0	+1·2	73	80	5·2	0	0	— 7·43
Ratnapura	88·6	+1·6	73·3	—0·2	79	95	7·8	8·78	20	— 9·23
Talawakele	73·4	+1·2	57·1	—1·2	82	94	6·2	2·61	14	— 7·45
Trincomalee	95·1	+3·2	77·9	+0·9	66	78	6·2	0·12	4	— 9·43

Rainfall in September was below normal practically over the whole Island, the larger deficits (exceeding 5 inches) being found among the central hills and to the west of them. The largest deficits were 16·77 inches at Kenilworth Estate, 16·13 inches at Watawala and 14·01 inches at Theydon Bois Estate. A few scattered stations recorded excesses, the only appreciable amounts being 3·46 inches at Topawewa and 2·62 inches at Yakkatuwa.

Rainfall was heaviest in the south-western low-country comprising Neboda-Morawaka area, where the monthly totals exceeded 10 inches, outstanding amounts being 18·33 inches at Kumbaduwa estate, 16·73 inches at Veddagala, and 15·86 inches at Gonapenigala estate. Outside the south-west quarter the rainfall was generally below 2 inches, the north-western parts and some parts of Batticaloa District receiving no rain at all.

The only daily fall over 5 inches was 6·35 inches at Topawewa on the 7th.

Temperatures were mainly above average. The highest recorded shade temperature was 98·0° at Trincomalee on the 29th and 30th, while the lowest air temperature was 46·3° at Nuwara Eliya on the 26th. Humidities were below average, and cloud amounts in deficit. The prevailing wind direction during the month was south-westerly.

D. T. E. DASSANAYAKE,
Superintendent Observatory.

5—J. N. A 84844 (12/48)

LIST OF ACQUISITIONS TO THE LIBRARY, DEPARTMENT OF AGRICULTURE, FOR THE PERIOD JULY 1 TO SEPTEMBER 30, 1948

BOOKS

1. Fisher and Yates—Statistical Tables for Biological, Agricultural, and Medical Research (3rd Edition).
2. Lawrence and Newell—Seed and Potting Compost (3rd Edition).
3. Miller and Robertson—Practical Animal Husbandry (latest Edition)—Issued to the Divisional Agricultural Officer, Horana.
4. Hayes and Immer—Methods of Plant Breeding (Issued to the Divisional Agricultural Officer, Horana).
5. Ellis—The Feeding of Farm Livestock (Issued to the Divisional Agricultural Officer, Horana).
6. Rice—Breeding and Improvement of Farm Animals (3rd Edition)—Issued to the Specialist in Animal Husbandry (Production).
7. Sanders—An Outline of British Crop Husbandry.
8. Baver—Soil Physics (2nd Edition).
9. Alston—The Kandy Flora (Issued to the Girls' Farm School, Kundasale).
10. Park and Fernando—Diseases of Village Crops in Ceylon (Issued to the Girl's Farm School, Kundasale).
11. Nielson-Jones—The Growing Plant.
12. Stewart and Crowther—Memoranda on Colonial Fertilizer Experiments.
13. Greig and Boddie—Hoare's Veterinary Materia Medica and Therapeutics (6th Edition).
14. Bennett—Soil Conservation (Issued to the Soil Conservation Officer).
15. Wrench—Reconstruction by Way of the Soil.
16. Lippincott and Card—Poultry Production (7th Edition)—(Issued to the Veterinary Research Officer).
17. Patterson—Statistical Technique in Agricultural Research (Issued to the Research Officer, Hambantota).
18. Nangpal—Insect Pests of Cotton in India.
19. Uppal—Diseases of Cotton in India.
20. Ferguson's Ceylon Directory, 1948.
21. Sandy—Dictionary of Engineering and Machine Shop Terms (Issued to the Agricultural Engineer).
22. Molloy—Modern Oil Engine Practice (Issued to the Agricultural Engineer).
23. Filley—Co-operation in Agriculture.
24. Burkill—A Dictionary of the Economic Products of the Malay Peninsula, Volumes I and II (Issued to the Girls' Farm School, Kundasale).
25. Kudo—Protozoology (3rd Edition).
26. Reports on the Progress of Applied Chemistry, 1947.
27. Block and Bolling—The Amino Acid Composition of Proteins and Foods.
28. Jacobs—The Chemistry and Technology of Food and Food Products, Volumes I and II.
29. Halnan—The Scientific Principles of Poultry Feeding (Issued to the Chemist).
30. Soil Erosion, its Prevention and Control—By the Government Press, Madras.
31. Agarwala, Chandra, Malhotra and Lal—Economic Planning and Agriculture.
32. Hayes—Fruit Growing in India.
33. Temple-Wright—Flowers and Gardens in India (8th Edition) (Issued to the Girls' Farm School, Kundasale).
34. Ghawalkar—Universal Ladies' Fashions (Issued to the Girls Farm School).
35. Nock—List of Plants of the Botanic Gardens, Hakgala, Ceylon (Issued to the Girls' Farm School, Kundasale).
36. Gunerathne—List of Plants of the Henaratgoda Botanic Gardens, Ceylon (Issued to the Girls' Farm School, Kundasale).
37. Plant List of the Royal Botanic Gardens, Peradeniya (Issued to the Girls' Farm School, Kundasale).
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